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Title: Effect of Interval Versus Continuous Exercise Training on Resting Energy Expenditure in Dieting College-Aged Women

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Changes in resting energy expenditure (REE) were investigated in 24 obese college-aged women during 12-weeks of exercise training on stationary bicycles. Twelve subjects comprised Group A and exercised at 85 percent of VO2peak in high intensity intervals of one to two-minutes in duration. The other 12 subjects comprised Group B and exercised at 60 percent of VO2peak in moderate intensity continuous bouts. Both groups completed 12,000, 16,875, and 22,500 kgm per exercise session for the first, second, and third four-week phases. Variables assessed at the conclusion of each phase were total body weight (Wt), absolute VO2peak (A VO2), relative VO2peak (R VO2), and REE. Variables measured only pre- and post-treatment were percent body fat (% Fat) and fat-free weight (FFW). A repeated measures mixed ANOVA design was used to test for significant ($p < .05$) difference.

Statistically significant changes were observed in both groups in the mean values of all variables except for FFW, which remained unchanged. Group A experienced 12.0, 19.0, 27.4, 45.1, and 53.4 percent changes in Wt, % Fat, A VO2, R VO2, and REE, respectively. Group B experienced 5.2, 8.8, 23.9, 31.2, and 23.6 percent changes in the same variables. It was concluded that high intensity interval training will also produce substantial improvement in the same parameters listed traditionally as appropriate goals of most aerobic exercise programs. For individuals who may have had a low rate of REE as the result of trying to lose weight by dietary restriction, high intensity interval training produced statistically significant increases in the REE after only four weeks. After 12 weeks the high intensity interval training program produced a 2.24 fold greater increase in the REE as compared to matched subjects who trained using moderate intensity continuous exercise.

Effect of Interval Versus Continuous Exercise Training on Resting Energy Expenditure in Dieting College-Aged Women

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CHAPTER I

INTRODUCTION

The role of exercise in achieving and maintaining desired body weight has been studied extensively in the past and continues to be at the forefront in present day weight loss treatments (ACSM, 1983; 1990). One of the primary goals of a successful weight loss program is to create a negative caloric balance, that is to have more calories of energy expended by the body than what is ingested. Stated in another way, you lose weight when energy expenditure is greater than energy intake. Exercise burns additional calories, both during the exercise session and for a period of time following exercise while the body recovers. It is generally believed that people who exercise more often will be able to consume more calories, thus creating a larger negative caloric balance.

The period of time following an exercise session for up to 12 hours has been studied intently because it has been found that there is more energy spent by the body during this period than what is needed to maintain homeostasis. This temporary elevated metabolic state was termed Excess Post-exercise Oxygen Consumption (EPOC) by Gaesser and Brooks (1984). Some of the processes believed to be responsible for EPOC are replenishment of oxygen stores in the blood and muscle, re-synthesis of ATP and creatine phosphate, lactate removal, increased ventilation, circulation, and body temperature (Bahr & Sejersted, 1991; Bangsbo et al., 1990; Gaesser & Rich, 1984; Sejersted & Vaage, 1987).

There are questions yet to be answered concerning the physiological mechanisms involved in EPOC; however, Bahr, Ingnes, Vaage, Sejersted, and Newsholme (1987) demonstrated that there is a positive linear relationship between the exercise intensity and duration and the length of time EPOC remains elevated. It has been hypothesized by many researchers that chronic exposure to physical activity, or frequent bouts of exercise leading to EPOC, create a physiological adaptation resulting in a higher resting metabolic rate (Poehlman, 1989; Poehlman & Horton, 1989; Poehlman, LaChance, & Tremblay, 1989; Bahr et al., 1987; Gore & Withers, 1990; and Bahr, Grønnerød, & Sejersted, 1992). This higher resting metabolic rate or resting energy expenditure (REE) appears to be the "Holy Grail" sought by individuals trying to maintain a negative caloric balance in order to facilitate weight loss.

The effect exercise has on energy expenditure by the body has been frequently mentioned in the human performance literature. Most researchers have reported higher basal and resting metabolic rates in individuals who exercise regularly versus sedentary populations (Margaria, Edwards, & Dill, 1933; Edwards, Thorndike, & Dill, 1935; Passmore & Johnson, 1960; deVries & Gray, 1963; Miller, Mumford, & Stock, 1967; Miller & Mumford, 1967; Segal, Gutin, Nyman, & Pi-Sunyer, 1985; Segal, Gutin, Albu, & Pi-Sunyer, 1987; and Poehlman, Melby, Badylak, & Calles, 1989). However, almost all of these studies have used apparently healthy, non-dieting subjects of normal weight. The results of these studies may not be generalizable to obese dieters.

Dieting results in a decrease in resting metabolic rate (Garrow, 1978), as well as decreases in energy expenditure for general activities or exercise (Apfelbaum, Bostarron, & Lacatis, 1971). Epstein, Woodall, Goreczny, Wing, and Robertson (1984) studied the energy expenditure patterns in obese young girls (ages 5-8 years) who also were dieting and found that the activity-induced enhancement of metabolic rate was consistent with previous reports on non-obese, non-dieting adults. However, the parameters necessary to prolong the enhanced metabolic rate and chronically change basal metabolisms were not reported. Lennon, Nagle, Stratman, Shrago, and Dennis (1985) were able to show a significant increase in the resting metabolic rate of obese, dieting subjects after 12 weeks of aerobic training but investigated only moderate intensity activities. Since the work of Lennon and co-workers in 1985 there have been no published studies which have looked at how much exercise, in terms of intensity and duration, produces the most beneficial increase in the resting metabolic rate in obese, dieting subjects.

In a pilot study, single bouts of exercise were performed by 20 high school-aged obese girls who were dieting. This study compared exercise durations of one-minute, six-minutes, 15-minutes, and 30-minutes, all at low, moderate, and high intensities (Siemann, unpublished). The results indicated that when measured eight hours post-exercise, only the REE's after exercise durations of six-minutes and 15-minutes at the high intensity pace were statistically significant. Following the pilot study, further investigation was suggested to determine what effects, if any, a regular program of high intensity training would have on REE.

Statement of the Problem

The purpose of this study was to investigate the effects of a 12-week training period in which both moderate and high intensity exercise was utilized in an attempt to alter the

REE in obese, college-aged females, who were also dieting. In particular, which form of exercise, moderate intensity performed in continuous sessions, or high intensity performed in short intervals, produced the greatest change in REE?

Definition of Terms

Basal Energy Expenditure (BEE) is also known as Basal Metabolism, and is the heat expended, measured in kilocalories per square meter of body surface area, by an individual at least 12 hours after the last meal, resting in a supine position, awake, at a normal body and ambient temperature, and without physical or psychological stress (Bursztein, Elwyn, Askanazi, & Kinney, 1989).

Dieting is a negative caloric balance in which the caloric equivalent of the food ingested is less than the total energy requirements of the body to maintain homeostasis and fuel physical activity.

Diet-Induced Thermogenesis (DIT) has also been known previously as specific dynamic action of nutrients (SDA), can be divided into obligatory and adaptive components (Rothwell & Stock, 1983). Obligatory thermogenesis, formerly known as SDA, is the energy cost of food intake and the subsequent conversion of food substrates (Bursztein et al., 1989). Adaptive diet-induced thermogenesis (formerly known as Luxuskonsumption) represents the dissipation of energy over and above that associated with the basal metabolic activity and the obligatory DIT (Bursztein et al., 1989).

Excess Post-Exercise Oxygen Consumption (EPOC) is the period of time immediately following an exercise session in which the energy expended by the body is in excess of that required to maintain homeostasis. Variables affecting the duration of EPOC are the intensity and duration of the exercise session. Higher exercise intensities and longer exercise durations result in longer EPOC periods.

High Intensity Exercise is equal to or greater than 85 percent of maximal oxygen uptake ($\dot{V}$O2peak). For the purposes of this study, the heart rate that was recorded when the subject was at 85 percent of $\dot{V}$O2peak during a maximal graded exercise test was used to identify high intensity exercise.

Indirect Calorimetry is an indirect estimate of energy metabolism based on the quantity of oxygen consumed under steady-state conditions. Using an open-circuit system an analysis of the difference in composition between the collected exhaled air and the ambient room air brought into the lungs reflects the body's constant release of energy (McArdle, Katch, & Katch, 1991).

Moderate Intensity Exercise is between 40 and 85 percent of $\dot{V}O2peak$. For the purposes of this study, the heart rate that was recorded when the subject was at 60 percent of $\dot{V}O2peak$ during a maximal graded exercise test was used to identify moderate intensity exercise.

Obesity has been difficult to quantify since the absolute percent body fat at which disease risk increases is controversial (ACSM, 1991). Several authors have labeled obesity in women as greater than 30 percent body fat (Heyward, 1991; Brown, 1992; McGlynn, 1993; Mullen, Gold, Belcastro, & McDermott, 1993; Williams, 1990). All subjects participating in the study had greater than 30 percent body fat

Resting Energy Expenditure (REE), also known as Resting Metabolism, is the heat expended, measured in kilocalories per square meter of body surface area, by an individual resting in a supine position, awake, at a normal body and ambient temperature, without physical or psychological stress, with the diet-induced thermogenesis included (Bursztein et al., 1989). In formula form, REE = BEE + DIT. In this study, REE was measured at least four hours after the last meal.

Delimitations

The subjects of this study were apparently healthy obese females, 19 to 25 years of age, who were currently restricting caloric intake in an effort to lose weight. The physiological response parameter under investigation was REE following a 12-week training program of either high intensity intervals or moderate intensity continuous training formats on a stationary bicycle. Pre- and post-test REE rates were determined at least four hours post-meal ingestion on days in which no physical activity had been performed.

Limitations

Metabolic rates were measured using an open circuit system in which exhaled gasses were collected and averaged over 20-second intervals. Variations in room air concentrations of oxygen and carbon dioxide, as well as breath-by-breath variations could not be identified.

The method utilized to calculate percent body fat using underwater weighing techniques incorporated an estimation of residual lung volume based on forced vital capacity. Laboratory equipment necessary to directly measure residual lung volume using helium dilution or nitrogen wash-out procedures was not available.

Participants were asked to continue their dietary practices throughout the study since any radical changes in the diet may have altered metabolic responses to the exercise treatment. Participants were also instructed to report any deviations in their diet. Participants were asked to limit their physical activity on the days in which they were not participating in the study to low intensity walking and stretching. On days in which training sessions were scheduled for the study, participants were asked to abstain from all other forms of exercise, outside that which was necessary to conduct normal daily activities in conjunction to attending school. It was felt that any outside physical training may have altered metabolic responses to the exercise treatment.

Assumptions

The following assumptions were made concerning the 12-week study design:

- 200 - 300 kcal/day dietary deficits were constant throughout the study;
- physical training, outside the treatment sessions, did not occur;
- REE values at 24 hours post-exercise reflected only the influences of the exercise treatments and were minimally influenced by test anxiety or outside environmental variables;
- any changes in the REE as a result of the treatment period did not reflect alterations in the metabolism due to EPOC but represented alterations to the adaptive component of the DIT and to a physiological change in the number of calories spent by the body to maintain homeostasis;
- the obligatory component of the DIT remained constant throughout the study; and
- readings obtained from the testing equipment reflected accurate values since calibration procedures were followed prior to each subject's assessment.

Hypotheses

A summary of the expected outcomes from the experimental treatment follows in Table 1. The variables percent body fat and maximal oxygen uptake represented descriptive statistics utilized to define the population and to determine workload settings for the participants, respectively. Their significance in this investigation did not necessitate formal testing for statistical significance. The purpose of this investigation was to study the effects of physical training on the REE.

Table 1 Expected Outcomes from Twelve Weeks of High Intensity Interval Training Versus Moderate Intensity Continuous Training in Obese, College-Aged Females Who Were Dieting

	Treatment Group	
Pre-Test to Post-Test	Group A	Group B
Physiological Variable	(high inten.)	(mod. inten.)
total body weight	↓	↓
percent body fat	↓	↓
maximal oxygen uptake	↑	↑
resting energy expenditure	↑	↑

To test whether or not the changes experienced by the participants were statistically significant, the following hypothesis, stated in the null form, was tested for $p < 0.05$ level of significance.

1. Ho: there is no significant difference in the mean REE of a group of obese, college-aged females who were dieting and trained using high intensity exercise in interval sessions versus the mean REE of a matched group who trained using moderate intensity exercise in continuous sessions at equivalent workloads.

   Ha: there is a significant difference in the mean REE of a group of obese, college-aged females who were dieting and trained using high intensity exercise in interval sessions versus the mean REE of a matched group who trained using moderate intensity exercise in continuous sessions at equivalent workloads.

The following critical value was used to test this hypothesis.

1. If $F(1, 22) > 4.30$ then reject Ho and accept Ha to conclude that there was a significant difference in the mean REE between a group of obese, college-aged females who were dieting; one group who trained for 12 weeks using high intensity exercise performed in one to two-minute intervals versus another group who also trained for 12 weeks but used moderate intensity exercise performed in continuous bouts.

CHAPTER II

RELATED LITERATURE

Exercise is Important to Help Maintain Weight Loss

Franklin (1984) reviewed 20 years of research which has focused on the effectiveness of various intervention strategies in the treatment of obesity. In his review only six percent of the studies investigated included an exercise component. He concluded: ". . . that caloric restriction (energy intake) rather than physical activity (energy expenditure) manipulations have been advocated more favorably (p 1)." This was interpreted to mean that more investigations have been performed which have included only dietary manipulations as compared to investigations which have included only exercise treatments or the combination of diet and exercise modifications in order to lose weight. Studies conducted by Mayer (1968), Thompson, Jarvie, and Lahey (1982), Zuti and Golding (1976), Volkmar, Strunkard, Woolston, and Bailey (1981), Strunkard and Penick (1979), Blair (1991), as well as studies reported in the ACSM "Position Stand on Proper and Improper Weight Loss" (1983), all recommend regular physical activity for people who have lost weight and wish to maintain the weight loss. Williams (1990) and Prentice (1991) both reviewed each of the studies reported in the ACSM "Position Stand on Proper and Improper Weight Loss" (1983), and concluded that individuals who achieved weight loss by diet alone experienced poor long-term compliance.

Severe Caloric Restriction Lowers the REE

There have been numerous studies which have demonstrated that large amounts of weight can be lost during periods of severe caloric restriction (Ballor, Johnson, Larson, and Hoerr, 1988; Dennison, 1982; Pavlou, Steffee, & Lerman, 1983; Abraham & Wynn, 1987; Donahoe, Lin, Kirschenbaum, & Keesey, 1984; Hewitt, Feleki, & Passmore, 1987; and Molé, Stern, Schultz, Bernauer, & Holcomb, 1989). However, as Franklin (1984) noted, and Molé et al. (1989) later demonstrated, there is a significant depression of the REE in dieters who are restricting caloric intake to levels below 1,000 kilocalories a day. Garrow (1978) even predicted that the body's adaptive lowering of the BEE and REE during periods of food deprivation may counteract the effect of dieting.

Chronic Exercise Raises the REE

Investigations studying the effects of various exercise intensities and durations to produce a training effect are numerous in the field of exercise science. The guidelines recommended by The American College of Sports Medicine (1991) advocate exercise intensities of 40 to 85 percent of VO2max or 55 to 90 percent of maximal heart rate for durations of 15 to 60 minutes in order to improve aerobic fitness. However, investigations specifically studying the effects of exercise intensity and duration on modifying the REE are limited.

Poehlman, Melby, Badylak, and Calles (1989); Poehlman, Melby, and Badylak (1988); Tremblay, Fontaine, and Nadeau (1985); and Tremblay et al. (1986) reported that young, endurance trained males had a higher REE than matched sedentary subjects. However, others have observed no statistically significant differences in REE between active and sedentary females who were matched for age, height, and weight (Jequier, 1983; Schutz, Bessard, & Jequier, 1984; and LeBlanc, Mercier, & Samson, 1984).

Poehlman, Melby, and Badylak (1991) compared REE in both young and older men who were matched for age, activity level, and body composition and found that the REE, when standardized to fat-free weight, was not significantly different in the younger subjects but was significantly different in the older subjects. With a significant difference in fat-free weight in older active subjects versus older sedentary subjects, they concluded that a long-term exercise program, one which maintains fat-free weight was needed to show differences in REE. They attributed the increased REE in active older men to the increased mass of active tissue.

Poehlman et al. (1991) also reported that even though the Diet-Induced Thermogenesis (DIT) represented only about 10 percent of the total daily energy expenditure, it was almost 40 percent higher in active young and older male subjects. This result was further supported in the female population by the findings of Jequier (1983), Schutz et al. (1984), LeBlanc et al. (1984) and Poehlman et al. (1989). Danforth (1981) suggested that the influence regular physical activity has toward the DIT is a major contributor toward long-term control of the energy balance.

In the 1930s several groups of investigators studied the effects of exercise on the REE and tried to define the time course and cause of the post-exercise increase in REE. Benedict and Sherman (1937); Edwards, Thorndike, and Dill (1935); and Schneider and Foster (1931) concluded that the energy expended during physical work is only a portion of the increase in total energy expended per 24-hour period. However, the central issue focuses on whether the elevated energy expenditure after acute exercise is the sole significant contributor to total energy expenditure. In their studies food intake was not controlled. In Benedict and Sherman's study in 1937, BEE was measured 12-hours after activity, but subjects were allowed to eat during their recovery period. Schneider and Foster (1931) measured their subjects in the morning, but again nothing was mentioned about requiring a 12-hour fast before measurement. The study conducted by Edwards et al. (1935) utilized Harvard football players and concluded that diets of 5,600 calories per day resulted in no significant weight loss or weight gain. Their BEE measurements were also taken in the morning following a 12-hour fast but in many instances also following a post-game "feast" in which caloric intakes were two to three times what was considered normal intakes. Poehlman and Horton (1989) suggested that all three of the earlier studies may have exaggerated the carry over effect of exercise on the BEE.

The Acute Effects of Exercise on the REE

Poehlman and Horton (1989) suggested that exercise may affect REE and DIT in three ways: 1) a prolonged increase in REE due to the residual effects of the exercise bout, termed Excess Post-Exercise Oxygen Consumption or EPOC by Gaesser and Brooks (1984); 2) a potentiating effect on energy expenditure when food is consumed in close temporal proximity to exercise; and 3) a physical conditioning effect resulting from regular participation in physical activity.

Some investigators have reported a quick and rapid decline of energy expenditures to REE after exercise (Brehm & Gutin, 1986; Pacy, Barton, Webster, & Garrow, 1985; and Poehlman, LaChance, & Tremblay, 1989); whereas others have found an elevated metabolic rate for almost 24 hours after the exercise session (deVries & Gray, 1963; Bessard, Schutz, & Jequier, 1983; Bielinski, Schutz, & Jequier, 1987; and Devlin & Horton, 1986).

Brehm and Gutin (1986) varied the intensity and duration of various bouts of exercise on trained men and reported that energy expended during recovery from the bouts amounted to values between 3 to 17 kcal. The highest post-exercise energy expenditure followed exercise at 75 percent of HRmax but lasted only 20 minutes in duration. Pacy et al. (1985) also reported that there were no significant differences in REE measured 20 minutes following exercise sessions lasting 30 minutes in duration. However, exercise intensity was not reported in their study.

Gore and Withers (1990) studied exercise intensities of 30, 50, and 70 percent of VO2max for durations of 20, 50, and 80 minutes on nine male subjects. Average age for their subjects was 21.9 years and average $\dot{V}$O2max capacity was 63.0 ml•kg-1•min-1. With this population of highly fit individuals, the elevation in the REE was statistically significant eight hours post-exercise only after the 70 percent of $\dot{V}$O2max intensity session. It was statistically significant with all three durations, however.

Bahr et al. (1987) investigated exercise durations of 20, 40, and 80 minutes, all at 70 percent of VO2max intensities using six highly fit male subjects. Oxygen uptake, respiratory exchange ratio, and rectal temperatures were monitored while the subjects rested in bed 24 hours post-exercise. They concluded that EPOC increases linearly with exercise duration and statistically significant elevations in EPOC were observed up to 12 hours post-exercise for all exercise durations. There were no statistically significant elevations observed after 24 hours.

Poehlman et al. (1989) noted a statistically significant elevation in REE 12 hours post-exercise following a single bout of exercise lasting 90 minutes in duration at an intensity of 50 percent of $\dot{V}$O2max. They re-assessed REE at 24 and 48 hours post-exercise but did not detect a statistically significant difference from the REE measured prior to the exercise bout . They did not, however, monitor the subjects continuously following the exercise session. Consequently, there may have been differences experienced at other times which were not recorded.

Bahr, Grønnerød, and Sejersted (1992) studied the acute effects of supramaximal exercise (108 percent of $\dot{V}$O2max) performed in two-minute intervals by six male subjects. The intervals selected were three, two-minute intervals, two, two-minute intervals, and one, two-minute interval. Originally they hypothesized that the elevated REE was due to elevated lactate levels. Consequently, the intervals chosen were selected based on Nordheim and Vøllestad's work (1990) which demonstrated achievement of very high levels of muscle lactate. However, Bahr and co-workers were only able to observe elevated lactate levels for two hours post-exercise while REE remained elevated for 4 hours post-exercise and only following the three, two-minute interval session.

Devlin and Horton (1986) found an elevated REE for up to 12 hours post-exercise in trained men who exercised at high intensities. They attributed this effect to an increase in glycogen synthetase activity suggesting that depleted glycogen stores were being replenished.

From a historical point of view, Margaria, Edwards, and Dill (1933) demonstrated an increased resting metabolic rate 10 percent above basal for 48 hours post-exercise.

Edwards et al. (1935) also reported elevated metabolic rates 25 percent above basal that lasted 15 hours following vigorous exercise. Both studies measured the metabolic rates of Harvard football players following a game. Allen and Quigley (1977) re-calculated the additional energy expenditure resulting from the bouts of vigorous exercise reported in these two earlier studies and found the mean increase in REE to be 450 kcal.

According to Franklin (1984) and Poehlman et al. (1989) the most systematic study of the metabolic afteraffects of exercise was performed by deVries and Gray in 1963. The REE for two middle-aged male subjects was tested at 2-, 4-, 6-, and 8-hour intervals on days following either an exercise session or sedentary activity during a six-week exercise program. In this way the metabolic afteraffects of the exercise could be compared to days in which no activity was performed. In addition, the metabolic afteraffects of the exercise at the beginning of the study could be compared to those obtained at the conclusion of the study to determine if any training effects were achieved during the six weeks of regular activity. Results showed that there was a 7.5 percent higher REE, measured four hours post-exercise, which remained elevated to six hours post-exercise, and returned to control day levels eight hours post-exercise at the onset of the study. At the conclusion of the study, REE was 28 percent higher, measured four hours post-exercise, but still returned to control day levels eight hours-post exercise. The total increase in energy expenditure attributed to the metabolic afteraffects of the exercise calculated by deVries and Gray was 53 kcal per day.

While both Franklin (1984) and Poehlman et al. (1989) concur that the study conducted by deVries and Gray (1963) represented the most carefully controlled study design involving metabolic measurements following exercise, the workloads reported during the cycle ergometer portion at the conclusion of the treatment period were three minutes at 7,425 ft. lbs•min-1 for one subject and ten minutes at 6,880 ft. lbs•min-1 for the second subject. This is equivalent to 360 kgm•min-1 and 250 kgm•min-1, respectively, or 1.2 and 0.8 kiloponds at a pedal cadence of 50 revolutions per minute. Both workloads could be considered low intensity exercise for most adult populations studied. Hence, what one group considers "vigorous" exercise certainly could be interpreted otherwise by a different population.

Bahr and associates (1987) observed elevated REE values up to 12 hours post-exercise following exercise intensities of 70 percent of VO2max for durations of 20, 40, and 80 minutes. Devlin & Horton (1986) also noted elevated REE values up to 12 hours post-exercise following high intensity exercise. These findings suggest that the REE should be assessed at least 12 hours after an exercise session. This should prevent an elevated REE as the result of any EPOC associated to the exercise session. For the purposes of this study, REE was measured 24 hours after the last exercise session. The studies conducted by Bahr and co-workers (1987) and Poehlman, LaChance, & Tremblay (1989) did not detect a statistically significantly difference in the REE measured 24 hours post-exercise when it was compared with pre-exercise REE.

Possible Factors Causing An Elevation in the REE

Miller, Mumford, and Stock (1967) and Miller and Mumford (1967) first suggested that exercise potentiates the DIT. The basic question was whether the combined energy expenditure that results from the ingestion of the meal plus the energy expended during the exercise exceed the sum of the increases that occur with ingestion or with exercise alone. A series of papers by Segal and Gutin (1983); Segal, Gutin, Nyman, and Pi-Sunyer (1985); and Segal, Gutin, Albu, and Pi-Sunyer (1987) reported that exercise has a potentiating effect on postprandial thermogenesis; that is, exercise of longer durations and of higher intensities increases DIT more than exercise of shorter durations and of lower intensities. They also found that in all cases DIT following any exercise is greater than DIT following no exercise. Segal et al. (1987) concluded that the effect exercise has on DIT is very much related to body composition. While the mechanism remains unclear, their work suggests that insulin sensitivity may play a key metabolic role in the interaction between physical activity and the magnitude of DIT. Devlin and Horton (1986) showed that insulin increased thermogenesis in skeletal muscle after exercise and speculated that insulin resistance, observed in obese individuals, blunts the capacity to increase energy expenditure when exercise is combined with food ingestion. Hence, when lean and obese individuals were compared, the degree of increased DIT associated with exercise was always higher in the lean subjects.

However, investigations conducted by Dallosso and James (1984) and Welle (1984) failed to observe any additive effect between exercise and food ingestion, even in lean individuals. Also contributing to the uncertainty was the study reported by Schutz, Bessard, and Jequier (1987). They observed no difference in lean and obese individuals in terms of the increase in DIT as a result of exercise.

Recent studies by Poehlman et al. (1989); Tremblay et al. (1986); Lawson, Webster, Pacy, and Garrow (1987); Lennon, Nagle, Stratman, Shrago, and Dennis (1984); and Poehlman et al. (1989) have shown that prolonged exercise training influences REE and DIT independent of body composition. These observations suggest that once a person "achieves a training state" as a result of physical exercise, REE and DIT are affected in a manner that, according to Poehlman and Horton (1989), is not due to the residual effects of the last bout of exercise. Tremblay et al. (1986) reported a ten percent higher REE in trained men as compared with untrained men. In the same study obese women demonstrated an eight percent increase in REE after an 11-week training program. Studies by Lawson et al. (1987) showed that women had an elevated REE after participating in a regular program of exercise. Poehlman et al. (1986) found that trained men had a higher REE than untrained men of similar fat-free weight. Poehlman et al. (1989) compared a wide range of fitness levels ($\dot{V}O_2max$ from 40 to 80 ml•kg-1•min-1) and concluded a significant positive relationship ($r = 0.77$; $p < 0.01$) was found between VO2max and REE.

<u>Exercise Training in Subjects Who Are Dieting</u>

The decline in REE during periods of caloric restriction is a well documented phenomenon. Garrow (1978) showed that an eight-week program of dietary restriction between 200 to 300 kcal/day below that considered necessary for basal requirements produced a 3.7 percent decline in BEE. In this study, however, no mention was made as to what activities, if any, the subjects participated in.

Apfelbaum, Bostarron, and Lacatis (1971) demonstrated a statistically significant lowering of REE in six obese subjects who followed a 500 kcal/day negative caloric balance. Their study reported a four percent decline in REE after six weeks. They also reported a ten percent decline in $\dot{V}O_2max$. However, this was predicted by treadmill times following a Bruce protocol, and metabolic measurements were not reported. Again, like Garrow's study in 1978, there was no mention of any outside activity patterns in the subjects participating in the study.

Epstein, Woodall, Goreczny, Wing, and Robertson (1984) studied 19 obese females, ages five through eight years, for five weeks during a summer camp where meals were provided to produce a negative caloric balance. Twice a week the subjects were monitored during play time using heart rate telemetry. In addition, two independent observers rated each subjects' activity level on a Likert scale. Based on a heart rate/kcal curve developed by Spady (1980) energy expenditure during each activity period was determined. Pre- and post-treatment tests of respiratory quotients (RQ) achieved at specific workloads of 150, 225, and 300 kgm•min-1 showed a statistically significant improvement in the group that received positive reinforcement for active play versus the control group that did not receive any encouragement. Both groups showed a statistically significant weight loss during the five-week treatment but the weight loss experienced by one group was not statistically significant from the other group. Average weight loss was one pound per week. Epstein and co-workers did not report the degree of caloric restriction.

Lennon and associates (1985) investigated the combined effects of aerobic activity and caloric restriction on 78 obese adult subjects (38 male, 40 female) with a mean age of 34.2 years. The treatment period was divided into three, four-week segments. Diet was maintained at 1,800 kilocalories per day for the first four-week segment, 1,500 kilocalories per day for the second four-week segment, and 1,200 kilocalories per day for the third four-week segment. This corresponded to a "normal," 300 kcal/day, and 600 kcal/day dietary deficit respectively. Over the 12-week treatment one group participated in self-selected aerobic activity for 30 minutes daily while a second group participated in stationary cycling every other day at workloads which maintained a heart rate intensity between 65 to 75 percent of age-predicted maximal heart rate for 20-minute durations. A third group participated in the dietary restriction portion but acted as a control group for the exercising groups and did not engage in any regular activity. Percent changes in $\dot{V}O2max$ values, predicted from treadmill times following a Bruce protocol, were statistically significantly in both exercise groups as compared to their pre-study times and a higher percent change was demonstrated by the daily self-selected exercise group. Percent changes in $\dot{V}O2max$ reported were non-significant for the control group, 9.0 $\pm$ 12 for the monitored exercise group, and 12.0 $\pm$ 9 for the self-selected exercise group. Percent changes in REE were -2.0 $\pm$ -9 for the control group, 4.0 $\pm$ 7 for the monitored exercise group, and 10.0 $\pm$ 9 for the self-selected exercise group. Consequently the control group experienced a two percent reduction in REE after eight weeks of diet alone while the groups that utilized regular exercise saw a four and ten percent elevation in REE. Even though the self-selected exercise group experienced the most advantageous benefit from the treatment period, and their workloads were not quantified, the authors concluded that the activity sessions were moderate in intensity. However, with changes based on VO2max values estimated solely on treadmill times and a lack of quantification of the self-selected exercise group's exercise workload, any results obtained from this study should be carefully evaluated for scientific significance. To the authors' credit, though, the number of participants was commendable.

Since the report by Lennon and associates in 1985, there have been no studies published in English which have investigated various intensities of exercise and their relationship to the REE of obese, female subjects.

In a pilot study conducted by Siemann (unpublished) in 1992, the acute effects of single bouts of exercise at various intensities and durations were investigated using 20 high school-aged girls who were dieting. Three consecutive one-day food intake diaries were collected over an 11-week period on three separate occasions to monitor dietary intake status. Daily caloric intakes were evaluated using *The Food Processor* (ESHA Research, 1985) software. Single bouts of treadmill exercise were performed at low (< 55 percent of HRmax), moderate (55 to 89 percent of HRmax), and high (≥ 90 percent of HRmax) intensities for durations of one-minute, six-minutes, 15-minutes, and 30-minutes. The REE values were recorded immediately before each exercise session and compared to REE values recorded eight hours post-exercise. Statistically significant differences were observed only after the high intensity sessions of six-minute and 15-minute durations. None of the subjects could complete a 30-minute session at high intensity. There were no statistically significant differences when post-test values of $\dot{V}O_2max$ or REE were compared to pre-test scores in a paired *t*-test.

Measuring Metabolic Rates

Bursztein, Elwyn, Askanazi, and Kinney (1989) suggested that, in bed ridden patients who were not on ventilators, there may be sufficient discomfort wearing nose clips and a mouthpiece in collection periods exceeding ten to 15 minutes to produce inaccurate results. They attributed these inaccuracies to an increase in ventilatory rate caused by hyperventilation. Griffiths, Payne, Stunkard, Rivers, and Cox (1990) measured adolescent children by resting them for 30 minutes or until a plateau was achieved, then a minimum ten-minute recording of oxygen uptake was made. Epstein and associates (1984) measured obese young girls, ages five through eight, and based REE on a five-minute collection period at least four hours after eating and just before an exercise session. The study conducted by deVries and Gray (1963) measured metabolic rates following a minimum rest period of ten minutes and then collected expired gasses over two-minute intervals until two identical readings were collected consecutively. Leff, Hill, Yates, Cotsonis, and Heymsfield (1987), while conducting reliability studies for various makes of metabolic measuring carts, demonstrated that REE values fluctuated greatly over a 24-hour period. However, Hester and Larson (1989) further reviewed the work of Leff and associates and concluded that REE measured using a properly calibrated metabolic cart could be made "in only a few minutes" (p. 101).

In the instruction manual accompanying the *Gould* metabolic cart, it was recommend that REE be assessed following at least a 15-minute rest period. Then the mouthpiece and nose clips should be attached and the subject monitored until ventilation rates (VE) plateau. Once a plateau was achieved, the *Gould* manual recommended averaging a ten-minute collection period to yield a REE. No references were cited, however, for this procedure.

Based on these studies, it appeared that REE should be measured after a minimum of 15 minutes rest, followed by a collection period that should not exceed 15 minutes in duration in which the subject was attached to the mouthpiece and wearing nose clips. Once ventilation rates plateau, all of the remaining values recorded should be averaged. Even if the subject demonstrated an early plateau, the minimum collection period would be ten minutes in duration.

CHAPTER III

METHODS AND PROCEDURES

Informed Consent

Prior to subject recruitment a formal review of methods and procedures was conducted by the Frostburg State University Institutional Review Board/Institutional Animal Care and Use Committee. After approval subjects received full disclosure of the research study, were presented an opportunity to ask questions for purposes of clarity, and given a written copy of the informed consent. A sample informed consent form appears in Appendix A. The informed consent form was then taken home by the subjects to review without any pressure to participate. Once this had been returned the subject was given another opportunity to ask questions before formal informed consent was administered. During all contacts concerning informed consent subjects were reminded of:

- explanation of the testing procedures;
- risks and discomforts;
- responsibilities of the subject;
- benefits to be expected;
- opportunity for inquiries;
- freedom of consent;
- rights of confidentiality.

Subjects

Twenty-four apparently healthy college-aged females were recruited from a list of students who enrolled in a freshman-level "Personalized Health and Fitness" course at Frostburg State University during spring semester of 1993. Before the study began, each subject was given an opportunity to become familiar with the testing procedures, metabolic rate determination, and stationary bicycle exercise. Subjects were also instructed how to rate exertion levels based on Borg's Scale of Perceived Exertion (Borg & Linderholm, 1967) and how to put on and operate the heart rate monitors used to regulate exercise intensity.

Two criteria were important to establish a homogeneous group: 1) the subjects must have been obese and 2) they must have been dieting at a caloric intake level low enough to create a negative caloric balance. Preliminary evaluations included estimation of percent body fat by hydrostatic weighing following the procedures outlined by McArdle, Katch, and Katch (1991). Subject selection was based upon a percent body fat greater than 30.

The potential subjects meeting the first criteria were then given an early morning appointment to have their REE measured. They were instructed to not eat anything after 6:00 PM on the evening preceding their appointment, to not exercise the day before, and to spend the least amount of energy as possible in traveling to the lab for testing. They were also instructed to fully void their bladders prior to their appointment.

Once they arrived at the lab for assessment, they were first weighed without shoes and then allowed to rest in a supine position for 15 to 30 minutes. Then they were fitted to a sterilized Hans Rudolph mouthpiece, and noseclips were attached. Remaining in a supine position, each subject was monitored until a plateau was achieved in the $\dot{V}E$. Once this plateau was achieved, the remaining collection values were averaged to determine REE. A minimum collection period of ten minutes was used before the values measured were averaged to determine the REE. From the time the mouthpiece and noseclips were fitted, the total collection time did not exceed 15 minutes. If the subject could not achieve a plateau in the first five minutes of collection, the mouthpiece and noseclips were removed, and, following a second fifteen minute supine rest, the subject was allowed to repeat the sequence. If a plateau was not achieved the second time, an appointment was made for the subject to come back at a later date. Averaged values were reported for each subject and denoted REE. The REE was assessed for each subject a total of four times throughout the study design. The pre-treatment REE was measured before the 12-week treatment began; REE was also measured during week four and week eight to calculate adjustments in the dietary deficit; and post-treatment REE was collected in the week following the last treatment session.

Following the completion of the initial REE assessment, instructions in how to record a three-day food intake diary were given to the subjects. Once three days' worth of total nutrient intake was recorded and turned in it was analyzed using *The Food Processor* dietary analysis software (ESHA Research, 1985). A mean daily caloric intake was computed from the three-day record. These values were reported for each subject and denoted caloric intake. Three-day dietary records were collected from each subject every week. It was felt that routine records would encourage participants to stick with their diets and the records turned in for analysis would better represent true eating behaviors. Only those records reported during week four and week eight were utilized to adjust caloric deficits.

Average daily caloric expenditures were estimated by first taking the predicted BEE, which was determined using body surface area and the procedures developed by McArdle et al. (1991). This value, expressed in kcal per hour, was used for the time period which the subject was asleep. The REE, which was measured in the lab, expressed in kcal per hour, represented the time period in which the subject was awake, not exercising, and not eating. Dietary Induced Thermogenesis (DIT) was estimated at ten percent of the total caloric intake as suggested by McArdle et al. (1991).

Exercise energy expenditures were determined by the work performed during each exercise session. During weeks one through four, the workload was 12,000 kgm. This produced an energy expenditure of approximately 170 kcal per exercise session or 510 kcal for each week. During weeks five through eight, the workload was 16,875 kgm. This produced an energy expenditure of approximately 230 kcal per exercise session or 690 kcal for each week. During weeks nine through twelve, the workload was 22,500 kgm. This produced an energy expenditure of approximately 300 kcal per exercise session or 900 kcal for each week.

Total energy expenditure was estimated for the week by considering the following variables:

- weekly hours at a BEE rate;
- weekly hours at a REE rate;
- DIT for caloric intake; and
- energy expenditure for the treatment exercise sessions.

The formula utilized came from procedures outlined by McArdle et al. (1991) for the determination of human energy expenditure during rest and physical activity. Table 2 summarizes these procedures. Body surface area, age, and gender were the initial variables used by the procedures to determine the BEE rate.

An average daily caloric deficit of 200 to 300 kcal from the REE value measured was computed for each subject. Alterations in the current diet were suggested to bring each subject within the 200 to 300 kcal daily dietary deficit recommended by the A.C.S.M. (1983) in the position stand entitled "Proper and Improper Weight Loss Programs."

Table 2		Determination of Total Energy Expenditure			
Hours of Sleep	x	BEE rate	=	Basal Energy Rate	(1)
Hours of Rest and Light Work	x	REE rate	=	Resting Energy Expenditure	(2)
Total Calories Ingested	x	0.10	=	DIT	(3)
# Treatment Sessions/Week	x	kcal/session	=	Exercise Energy Expenditure	(4)
(1) + (2) + (3) + (4)			=	**Total Energy Expenditure**	

A maximal graded exercise test (GXT), following a modified Y.M.C.A. protocol (ACSM, 1991), was performed on a Monark Model 818E ergometer during a third pre-study appointment. Expired gases were collected and analyzed using a *Gould 9000 Cardiopulmonary Exercise System* metabolic cart. The VO2peak was determined at the point where $\dot{V}O2$ values failed to rise after a change in the workload and/or any A.C.S.M. (1991) endpoint for graded exercise testing of apparently healthy subjects was exhibited. Failure to maintain the pedal cadence at the revolutions per minute chosen by the subject at the beginning of the exercise test resulted in the termination of 22 out of 24 GXT's. After each test was concluded, $\dot{V}O2$peak was recorded and oxygen uptakes of 60 and 85 percent were computed. Heart rates corresponding to these two intensities were then noted along with the workloads eliciting these responses. These procedures were repeated during week four and week eight to allow adjustment of the treatment sessions so that exercise intensities remained within the desired levels.

Subjects were then randomly assigned into one of two treatment groups. Each subject was given an identification number ranging from one to 24. Then they were alternatively assigned between Group A or Group B depending on the order of their ID number as it appeared on a table of random numbers presented in Thomas and Nelson (1990). Once assigned to a treatment group, the subjects were reassigned an ID number. Numbers 1-12 represented subjects assigned to Group A, the high intensity, interval training group, and numbers 13-24 represented subjects assigned to Group B, the moderate intensity, continuous training group.

Testing procedures pre- and post-treatment were conducted following the same protocols by the author and one assistant. Table 3 identifies which variables were measured and at what time period during the study design. All instructions to the subjects and all data were recorded by the author.

Table 3 Variable Assessment Over the Course of the Study

Variable	Pre-Treatment	Week 4	Week 8	Post-Treatment
Body Weight	•	•	•	•
Percent Fat	•			•
Absolute $\dot{V}O2peak$	•	•	•	•
Relative $\dot{V}O2peak$	•	•	•	•
REE	•	•	•	•

Instrumentation

Indirect calorimetry was performed using an open circuit system in which room air was inhaled by the subject and exhaled gases collected and analyzed by a *Gould 9000 Cardiopulmonary Exercise System* metabolic cart following procedures outlined by the manufacturer. Heart rates were checked and recorded every minute with a *Polar* heart rate monitor. Exercise sessions were conducted on *Schwinn Airdyne* stationary cycles in which the resistance component is controlled by the cadence. A conversion chart prepared by the manufacturer appears in Appendix B showing the workload in kgm•min-1 for various pedal cadences. Exercise tolerance testing was performed using a *Monark Model 818-E* institutional ergometer, and calibration was completed according to the manufacturer's instructions prior to each graded exercise test.

Treatment Procedure

The overall study was divided into three segments, each four weeks in duration. The goal was to progress to the point where the total work performed during each exercise session required the uptake of 60 liters of oxygen, or approximately 300 kcal of energy. This value represents energy expenditure for a single exercise session as recommended by the A.C.S.M. (1983) in their position stand entitled, "Proper and Improper Weight Loss Programs." During the first segment, or weeks one through four, the workload selected required an energy output of 170 kcal. The second segment, weeks five through eight, required an energy output of 230 kcal of energy. The third segment, weeks nine through twelve, required an energy output of 300 kcal of energy. It was felt that participants would enjoy more success if allowed to progress up to the recommended levels, especially considering their initial degree of fitness.

Subjects were assigned to one of two groups. Group A performed high intensity exercise in intervals of one to two-minutes in duration. Group B performed moderate intensity exercise continuously for each exercise session. Both groups performed the same quantity of work during each exercise session measured in kilogram meters (kgm).

During the exercise sessions, each subject was fitted with a heart rate monitor and assigned to a stationary bicycle. Subjects progressed through a standardized warm-up period consisting of three minutes in which the pedal cadence was adjusted to elicit a heart rate of 100 bpm for the first minute, 120 bpm for the second minute, and then 130 bpm for the third minute.

After the warm-up period, subjects in Group A were instructed to increase their pedal cadence until the heart rate matched the heart rate recorded during a maximal graded exercise test (GXT) when the subject achieved a level of intensity which corresponded to 85 percent of their VO2peak. This cadence was then maintained as long as possible for an interval of at least 60 and no longer than 120 seconds. Each subject had a different interval time so that, at the conclusion of eight to ten intervals, the total work performed equalled the desired work output. At the conclusion of each interval, the subject stopped pedaling until their heart rate returned to 120 beats per minute. Target heart rates were maintained within plus or minus three beats per minute. Then the next interval began and the subjects resumed pedaling until heart rates returned to their target intensity. This procedure continued until each subject had completed the workload. Each subject was monitored throughout the interval for heart rate and timed on a stopwatch to insure the target workload was achieved. At the conclusion of each interval subjects were also asked for a rating of perceived exertion from Borg's Scale of Perceived Exertion (Borg & Linderholm, 1967). Results from a trial suggested that recovery periods between each interval should take 30 to 60 seconds. Total time for Group A, not counting the warm-up, was between 20 and 30 minutes for each exercise session.

After the warm-up period, subjects in Group B were instructed to increase their pedal cadence until the heart rate matched the heart rate recorded during a maximal graded exercise test (GXT) when the subject achieved a level of intensity which corresponded to 60 percent of their $\dot{V}O2peak$. Each subject was monitored at least once a minute so that adjustments could be made to insure heart rates stayed constant. Target heart rates were maintained within plus or minus three beats per minute. Each participant was also asked to maintained within plus or minus three beats per minute. Each participant was also asked to rate their perceived exertion periodically throughout the exercise session. Similar to Group A, individual variations were possible by adjusting the pedal cadence. Unlike Group A, however, Group B pedaled continuously at a constant heart rate for each exercise session. Exercise session durations for Group B were 20 minutes during the first, 25 minutes during the second, and 30 minutes during the last three-week segment. Corresponding workloads were 12,000 kgm, 16,875 kgm, and 22,500 kgm.

At the conclusion of each week, subjects were asked to submit a consecutive three-day diary of their food intake. These diaries were analyzed using *The Food Processor* dietary analysis software (ESHA Research, 1985) to insure that the subjects were maintaining a 200 to 300 kcal/day dietary deficit. Throughout the study, subjects reviewed their dietary analyses in an attempt to alter food selection choices so that their diets were well balanced.

During week four and week eight, one of the exercise sessions for each subject was a repeat of the maximal GXT. Any training effects realized from the time of the first GXT were then noted and adjustments to the exercise intensity target were made. This allowed each subject to continue throughout the study design at the exercise intensity desired.

Data Collection

While the subject was connected to the metabolic cart the following parameters were measured/computed:

- volume of expired gases ($\dot{V}E$);
- volume of carbon dioxide ($\dot{V}CO2$);
- volume of oxygen ($\dot{V}O2$);
- respiration rate (RR);
- tidal volume (TV);
- respiratory exchange ratio (R); and
- kilocalories of energy expended (kcal).

Each variable was collected over 20-second intervals and averaged to yield a value expressed per minute. A sample printout appears in Appendix C. For each subject the following descriptive data were also recorded:

- date of test;
- room temperature;
- barometric pressure; and

To determine REE, urinary nitrogen was estimated at 10.6 g•day-1. This value represents an average urinary nitrogen value for this population group and, according to Bursztein et al. (1989), will lead to an error of no more than one to two percent over values calculated using 24-hour urine collections. Facilities and equipment available at Frostburg State University did not permit actual determination of nitrogen excreted by the analysis of 24-hour urine collections.

The parameter used in evaluating changes in REE was kcal of energy expended. Each kcal value represented an average of the 20-second collection periods recorded each minute. The number calculated by the computer for each 20-second interval was expressed as if the total number of kilocalories were expended in a 24-hour period. Thus, a reading of 1,235 kcal represented the metabolic rate extrapolated over a 24-hour period and expressed per square meter of body surface area. The calculated REE assumed the volumes of oxygen and carbon dioxide collected during that interval reflect REE for 24 hours. The REE reported during the study represented a mean of all values collected once VE rates achieved a plateau. The total time period of collection was at least ten minutes, but no longer than 15 minutes in duration.

Throughout the study design assessment of physiological variables were made a total of four times: once during the pre-treatment assessment, during week four, during week eight, and at the conclusion of the study during the post-treatment assessment. These variables included:

- Total Body Weight;
- REE;
- Absolute $\dot{V}O_2$peak; and
- Relative $\dot{V}O_2$peak.

Percent body fat and fat-free weight were also determined for each subject but were only measured during the pre- and post-treatment assessments.

Statistical Treatment

To determine if the changes experienced by the subjects throughout the study design were significantly different, a two by four mixed analysis of variance (ANOVA) with group as a between subjects factor and time as a within subjects factor design was used. Newman-Keuls post hoc analysis procedures were performed to identify in which group or at what time interval any statistically significant differences occurred. Correlation coefficients were also calculated to determine if any evidence of association was present between the variables. A *Macintosh* microcomputer using *Stat-View Version 4.0* software (Abacus Concepts, 1992) and *Statistica Release 3.0a* (A. B. Soft Corporation, 1992) was used to perform the computations. The alpha level was set at $p < .05$.

CHAPTER IV

RESULTS

The purpose of this study was to investigate the effects of a 12-week training period in which moderate and high intensity exercise were utilized in an attempt to alter resting energy expenditure (REE) in obese, college-aged females who were also dieting. Two groups were investigated. Group A was comprised of 12 subjects who performed stationary cycling exercise in one to two-minute intervals at a heart rate intensity corresponding to 85 percent of maximal oxygen uptake ($\dot{V}O2peak$). Group B also had 12 subjects, and they performed the same quantity of stationary cycling exercise as Group A. Group B, however, performed their exercise sessions in one continuous bout at a heart rate intensity corresponding to 60 percent of $\dot{V}O2peak$.

Two criteria were important to establish a homogeneous group: 1) the subjects must have been obese and 2) they must have been dieting at a caloric intake level low enough to create a negative caloric balance. Results from the pre-test appear in Table 4. The mean body fat percentage for Group A was 37.28 percent. The mean body fat percentage for Group B was 34.07 percent. Thus, using 30 percent as an indicator of obesity, all of the subjects were obese at the beginning of the study.

Table 4 Results from a Newman-Keuls Post Hoc Test for Significant Difference Between Groups for the Mean Pre-Treatment Values

Parameter	**Group A**	**Group B**	**Mean Diff.**	**P-Value**
Weight (kg)	87.63	84.12	3.513	$p < .001$
(St. Dev.)	8.55	7.56		
Percent Fat (%)	37.28	34.07	3.218	$p < .001$
(St. Dev.)	3.27	2.65		
Fat-Free Weight (kg)	55.01	55.56	.550	$p > .05$
(St. Dev.)	6.65	6.43		
Absolute $\dot{V}O_2peak$ ($L \cdot min^{-1}$)	2.318	2.160	.158	$p < .01$
(St. Dev.)	.294	.278		
Relative $\dot{V}O_2peak$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	26.57	25.68	.892	$p > .05$
(St. Dev.)	3.32	2.48		
REE ($kcal \cdot m^{2-1} \cdot day^{-1}$)	943.36	950.46	7.100	$p > .05$
(St. Dev.)	67.23	72.94		

Three consecutive one-day dietary intake records were collected and analyzed to determine pre-treatment average daily caloric intake. The mean caloric intake for Group A was 1,063.58 kcal per day, and 1,026.92 kcal per day for Group B. Caloric intakes ranged from 861 to 1,205 kcal per day. Pre-treatment caloric intakes for each subject appear in Appendix D.

The average pre-treatment REE was 943.36 kcal per day for Group A, and 950.46 kcal per day for Group B. The REE for both groups ranged from 820.08 to 1093.92 kcal per day. Pre-treatment REEs for each subject appear in Appendix D.

The mean pre-treatment daily caloric deficit was 265.38 kcal per day for Group A, and 306.85 kcal per day for Group B. Pre-treatment caloric deficits ranged from 179.61 to 391.65 kcal per day. Caloric deficits for each subject appear in Appendix F. Thus, using the dietary intake records, measured REE, and calculated basal energy expenditure from body surface area, age, and gender, the mean daily caloric deficit indicated that the subjects were dieting at a caloric intake level low enough to create a negative caloric balance at the beginning of the study.

Maximal graded exercise tests were performed on each subject to establish exercise intensities for each phase of the treatment design. $\dot{V}O2peak$ was utilized as an indicator of improvement in aerobic fitness. At the beginning of the study, the mean relative $\dot{V}O2peak$ was 26.57 ml•kg-1•min-1 for Group A, and 25.68 ml•kg-1•min-1 for Group B. In absolute terms, the mean $\dot{V}O2peak$ was 2.318 L•min-1 for Group A, and 2.160 L•min-1 for Group B. Relative $\dot{V}O2peak$ ranged from 20.01 to 31.37 ml•kg-1•min-1. Absolute $\dot{V}O2peak$ ranged from 1.682 to 2.859 L•min-1. Pre-treatment relative and absolute $\dot{V}O2peak$ scores for each subject appear in Appendix G.

The treatment sessions were divided into three phases, each four weeks in duration. Workloads corresponding to each phase were 12,000 kgm per exercise session during the first phase, 16,875 kgm per exercise session during the second phase, and 22,500 kgm per exercise session for the third phase. Table 5 presents changes that occurred over the course of the study from the treatment sessions for both groups.

Figure 1 depicts the mean changes in total body weight that occurred over the course of the study. Table 6 details these changes. The mean weight loss was 10.51 kilograms (23.12 pounds) for Group A, and 4.39 kilograms (9.66 pounds) for Group B. This represented a 12.0 percent change for Group A, and a 5.2 percent change for Group B. The main effect of time was statistically significant ($F(3, 66) = 161.8$, $p < .001$). This was evidenced by the steady decline in total body weight during each four-week phase as shown in Figure 1.

Table 5 Mean Scores Over the Course of the Study

Parameter	**Group A**	St. Dev.	**Group B**	St. Dev.
Body Weight (kg)				
Pre-Treatment	87.63	8.55	84.12	7.56
Week Four	85.86	8.44	83.33	7.31
Week Eight	80.00	7.33	82.22	7.30
Post-Treatment	77.12	6.96	79.73	6.97
Percent Body Fat (%)				
Pre-Treatment	37.28	3.28	34.07	2.65
Post-Treatment	30.18	2.47	31.07	2.23
Fat-Free Weight (kg)				
Pre-Treatment	55.01	6.64	55.56	6.40
Post-Treatment	53.86	5.48	55.01	5.68
Absolute $\dot{V}O_2$peak ($L \cdot min^{-1}$)				
Pre-Treatment	2.318	.2937	2.160	.2782
Week Four	2.458	.2533	2.241	.2120
Week Eight	2.628	.1412	2.412	.1467
Post-Treatment	2.954	.1380	2.675	.1730
Relative $\dot{V}O_2$peak ($ml \cdot kg^{-1} \cdot min^{-1}$)				
Pre-Treatment	26.57	3.32	25.68	2.48
Week Four	28.81	3.40	26.95	2.06
Week Eight	33.09	3.37	29.45	1.96
Post-Treatment	38.54	3.43	33.69	2.51
REE ($kcal \cdot m^{2-1} \cdot day^{-1}$)				
Pre-Treatment	943.36	67.23	950.46	72.94
Week Four	1,074.02	73.50	989.11	78.00
Week Eight	1,210.64	59.58	1,041.63	65.22
Post-Treatment	1,447.32	88.05	1,175.12	69.98

The interaction of group by time was also statistically significant ($F(3, 66) = 35.5$, $p < .001$) which indicates the change over time was different in the two groups. A Newman-Keuls post hoc analysis showed that there were significant differences ($p < .001$) in the mean total body weight of Group A versus Group B measured during the pre-treatment, week four, week eight, and post-treatment assessments. The mean total body weight for Group A was higher than Group B during the pre-treatment and week four assessments, then lower than Group B during the week eight and post-treatment assessments. This, in combination with the interaction effect, shows that the weight loss

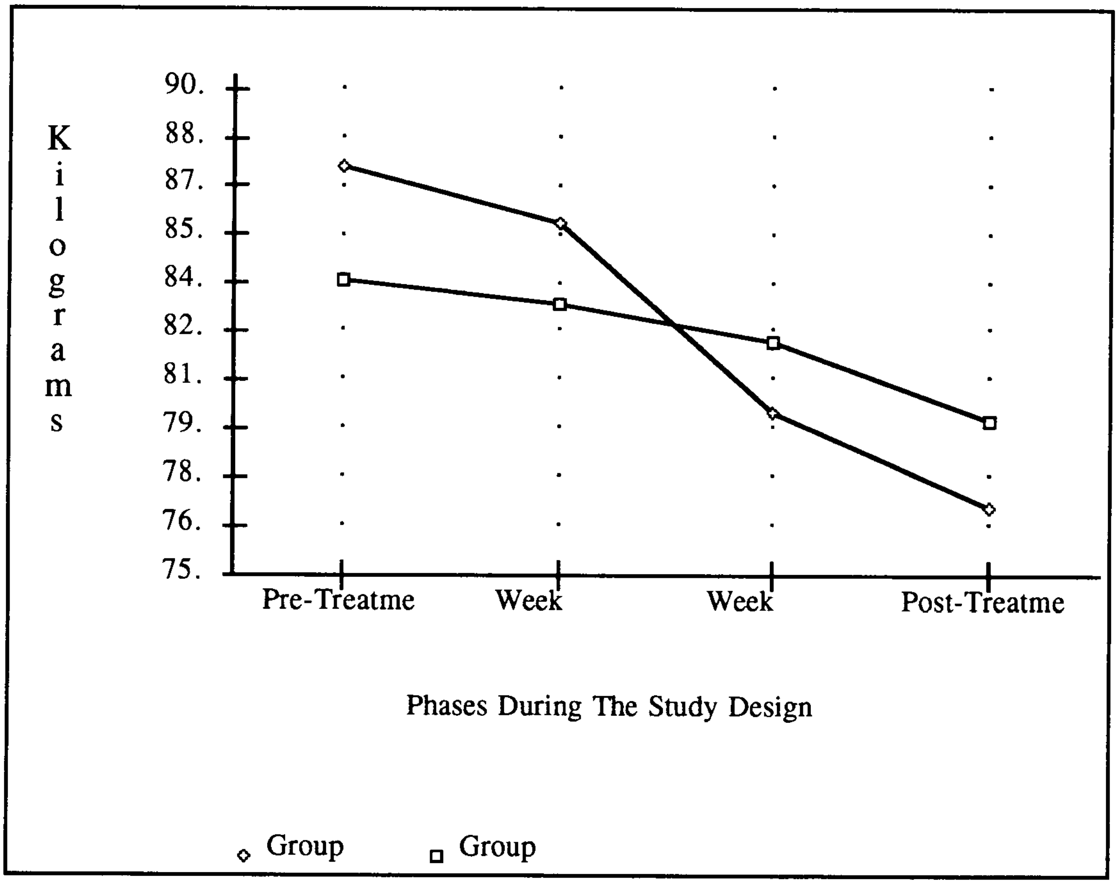

Figure 1 Mean Changes in Total Body Weight (Kg) Over the Course of the Study

experienced by Group A over the course of the study was significantly greater than the weight loss experienced by Group B. A complete listing of the statistical analyses appears in Appendix V.

Table 6 Mean Changes in Total Body Weight (Kg) Over the Course of the Study

		Treatment Phase		
Group	**Pre-**	**Wk 4**	**Wk 8**	**Post-**
A	87.63	85.86 *	80.00 *	77.12 *
B	84.12	83.33 *	82.22 ns	79.73 *
Mean Difference	3.51 *	2.53 *	2.22 *	2.61 *

* indicates a statistically significant difference ($p < .05$)

The mean weight loss for the first phase was 1.77 kilograms for Group A and 0.79 kilograms for Group B. A Newman-Keuls post hoc analysis showed that there was a significant difference ($p < .001$) between the mean weight loss experienced by Group A and that of Group B for the first four-week phase.

The mean weight loss for the second four-week phase was 5.86 kilograms for Group A and 1.12 kilograms for Group B. A Newman-Keuls post hoc analysis showed that there was a significant difference ($p < .001$) between the mean total body weight of Group A and that of Group B measured during the second four-week phase.

The mean weight loss for the third four-week phase was 2.88 kilograms for Group A and 2.48 kilograms for Group B. A Newman-Keuls post hoc analysis showed that there was a significant difference ($p < .001$) between the mean total body weight of Group A and that of Group B measured during the third four-week phase.

Thus, for the variable total body weight, there was evidence to suggest that interval training, performed at a high intensity in one to two-minute intervals, produced more of a loss in total body weight, than did continuous training, performed at a moderate intensity. Further, this weight loss was significant after four weeks, and the rate of weight loss was greater over the 12-week treatment in Group A.

Table 7 details the mean changes in percent body fat that occurred over the course of the study. Figure 2 depicts these changes. The mean reduction in percent body fat was

7.10 percent for Group A, and 3.00 percent for Group B. This represented a 19.0 percent change for Group A, and an 8.8 percent change for Group B. The main effect of time was statistically significant ($F(1, 22) = 164.3$, $p < .001$). But there were no measurements of percent body fat during the fourth week or the eighth week. Consequently, it cannot be determined when, during the course of the study, more changes were made. The interaction of group by time was also statistically significant ($F(1, 22) = 27.2$, $p < .001$) which indicated the change over time was different in the two groups. The main effect of group was not statistically significant ($F(1, 22) = 1.3$, $p > .05$), however. Results of an unpaired t-test, reported earlier in Table 4, showed that the mean pre-treatment percent body fat scores of Group A were significantly different ($T(22) = 2.647$, $p > .05$) than the mean pre-treatment percent body fat scores of Group B. A Newman-Keuls post hoc analysis also showed that there was a significant difference ($p < .001$) in the mean pre-treatment percent body fat scores of Group A versus Group B. A Newman-Keuls post hoc analysis showed that there was no significant difference ($p > .05$) in the percent body fat of Group A in comparison to Group B measured during the post-treatment assessment. Thus, for the variable percent body fat, even though there was no significant difference in the mean post-treatment percent body fat values of Group A versus Group B, there was statistical evidence to show that Group A experienced more of a reduction in percent body fat than Group B. This was due to the fact that Group A began the study with a higher percent body fat than Group B.

Table 7 Mean Percent Body Fat Over the Course of the Study

Group	**Pre-Treatment**	**Post-Treatment**	**Change**
A	37.28	30.18	7.10 *
B	34.07	31.07	3.00 *
mean difference	3.21 *	0.89 ns	4.10 ns

* indicates a statistically significant difference ($p < .05$)

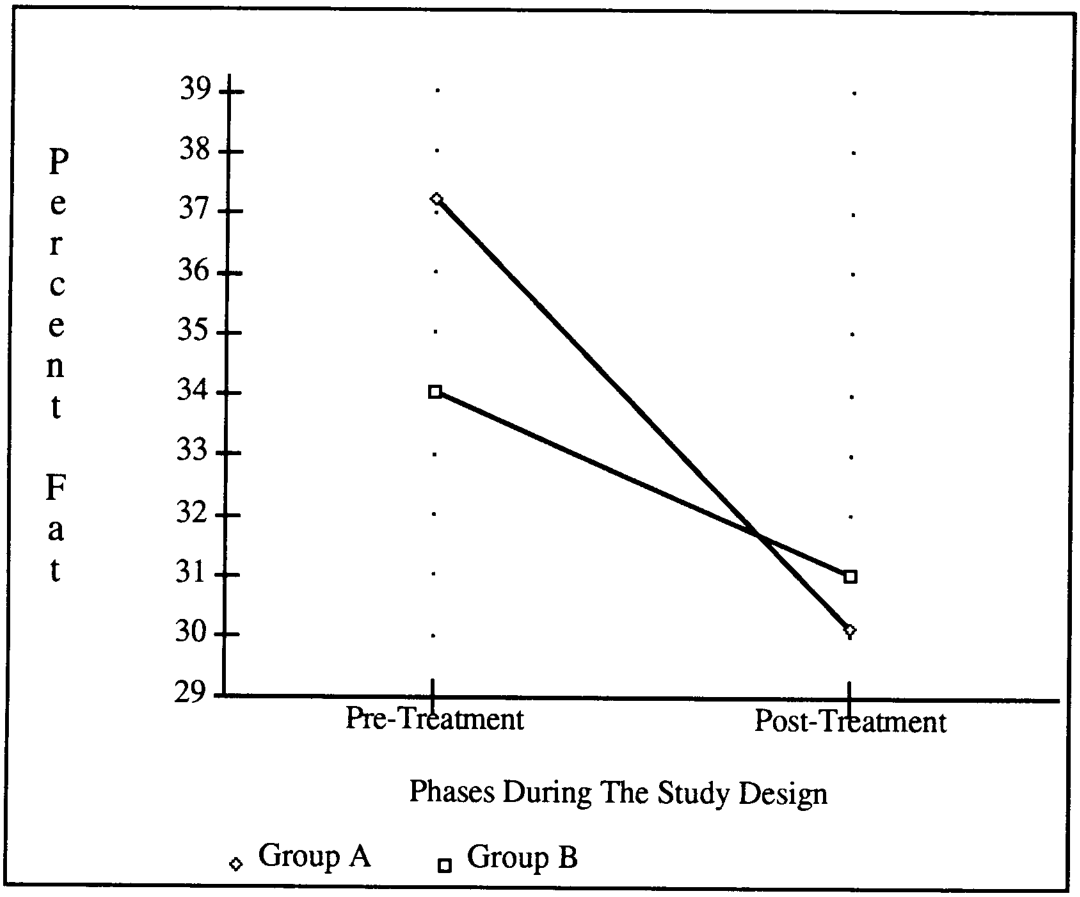

Figure 2 Mean Changes in Percent Body Fat Over the Course of the Study

Table 8 presents the mean changes in fat-free weight that occurred over the course of the study. Figure 3 depicts these changes. The mean change in fat-free weight was a 1.14 kilogram (2.5 pound) reduction for Group A, and a 0.55 kilogram (1.2 pound) reduction for Group B. This represented a 2.1 percent change for Group A, and a 1.0 percent change for Group B. The main effect of time was not statistically significant ($F(1, 22) = 2.4$, $p > .05$). This was evidenced by the near horizontal line in Figure 3. The interaction of group by time was also not statistically significant ($F(1, 22) = 0.3$, $p > .05$) which indicated that the change over time was not different in the two groups. Thus, for the variable fat-free weight, there was no evidence to suggest that there was a significant difference in the fat-free weight after 12 weeks of exercise training.

Table 8 Mean Changes in Fat-Free Weight (Kg) Over the Course of the Study

Group	Pre-Treatment	Post-Treatment	Change
A	55.01	53.87	1.14 ns
B	55.56	55.01	0.55 ns
mean difference	0.55 ns	1.14 ns	0.59 ns

ns indicates no statistically significant difference ($p < .05$)

Table 9 details the mean changes in absolute $\dot{V}$O2peak that occurred over the course of the study. Figure 4 depicts these changes. The mean change in absolute $\dot{V}$O2peak over the 12-week treatment period was a 0.635 liter per minute increase for Group A, and a 0.515 liter per minute increase for Group B. This represented a 27.4 percent increase for Group A, and a 23.9 percent increase for Group B. The main effect of group was statistically significant ($F(1, 22) = 7.9$, $p < .05$). A Newman-Keuls post hoc analysis also showed that the mean pre-treatment, week four, week eight, and post-treatment absolute $\dot{V}$O2peak measures were significantly different ($p < .01$) in Group A versus Group B. An unpaired t-test did not, however, detect a significant difference ($t(22) = 1.356$, $p > .05$) between the pre-treatment measures of absolute $\dot{V}$O2peak in Group A versus Group B. The main effect of time was statistically significant ($F(3, 66) = 115.8$, $p < .001$). This was evidenced by the slope of the line in Figure 4. Also, a Newman-Keuls post hoc analysis showed that there was a significant difference ($p < .001$) in the mean absolute $\dot{V}$O2peak

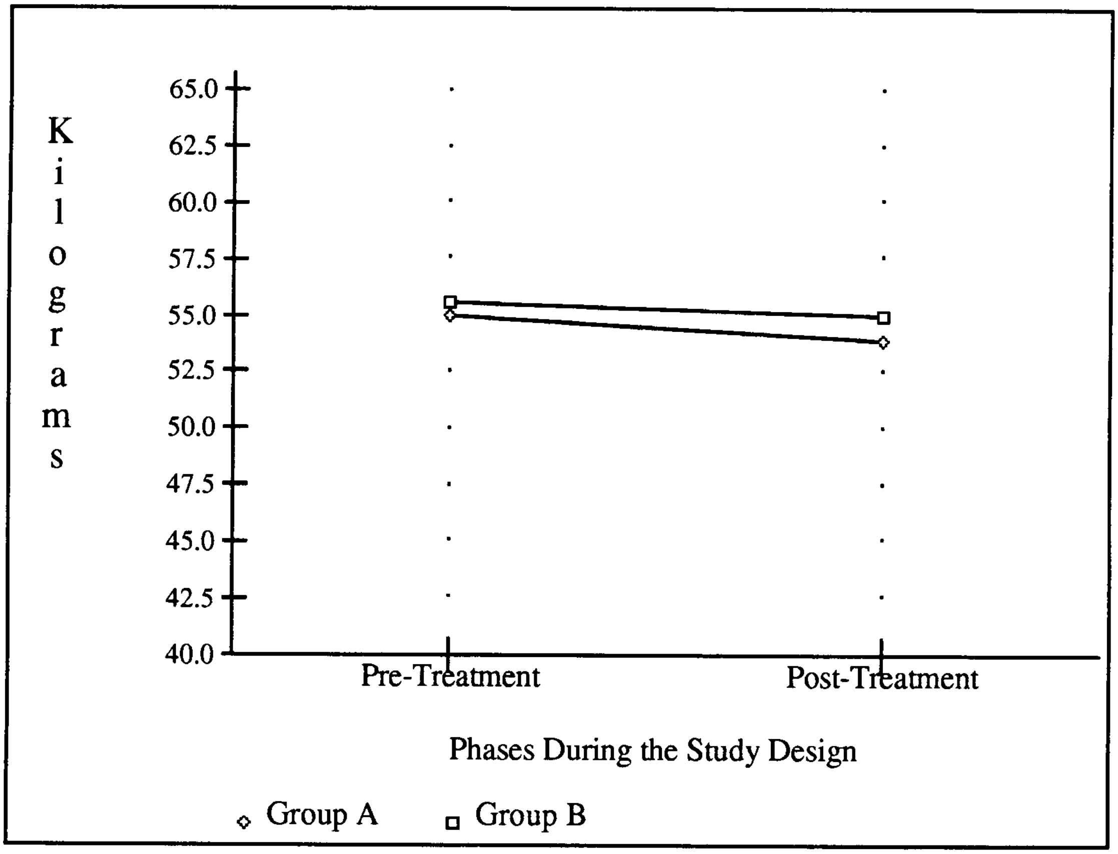

Figure 3 Mean Changes in Fat-Free Weight (Kg) Over the Course of the Study

values for Group A measured from the pre-treatment to week four, week four to week eight, and week eight to the post-treatment assessment. The same pattern of significant differences ($p < .001$) was also exhibited by Group B. The interaction of group by time was not significantly different ($F(3, 66) = 1.1$, $p > .05$) which indicated that the change over time was not different in the two groups. Thus, for the variable absolute $\dot{V}O2peak$, there was evidence to suggest that there was a significant improvement in $\dot{V}O2peak$ experienced by both groups, but since they began the treatment with different scores, there was no evidence to show that one group improved more than the other.
Hence, exercise in general, and not specifically exercise at a high intensity performed in intervals or exercise at a moderate intensity performed in continuous bouts, produced a statistically significant improvement in absolute $\dot{V}O2peak$.

Table 9 Mean Changes in Absolute $\dot{V}O2peak$ (L•min-1) Over the Course of the Study

Group	Pre-	Treatment Phase Wk 4	Wk 8	Post-
A	2.318	2.458 *	2.628 *	2.954 *
B	2.160	2.241 *	2.412 *	2.675 *
Mean Difference	0.158 *	0.217 *	0.216 *	0.279 *

* indicates a statistically significant difference ($p < .05$)

Table 10 details the mean changes in relative $\dot{V}O2peak$ that occurred over the course of the study. Figure 5 depicts these changes. The mean increase in relative $\dot{V}O2peak$ was 11.97 ml•kg-1•min-1 for Group A, and 8.01 ml•kg-1•min-1 for Group B. This represented a 45.1 percent improvement for Group A, and a 31.2 percent improvement for Group B. The main effect of group was statistically significant ($F(1, 22) = 7.1$, $p < .05$). A Newman-Keuls post hoc analysis showed that the mean relative VO2peak was significantly different ($p < .01$) during week four in Group A versus Group B. The mean relative VO2peak was also significantly different ($p < .001$) during the week eight and the post-treatment assessments in Group A versus Group B. There was no significant difference ($p > .05$) in the pre-treatment mean relative $\dot{V}O2peak$ values in Group A versus

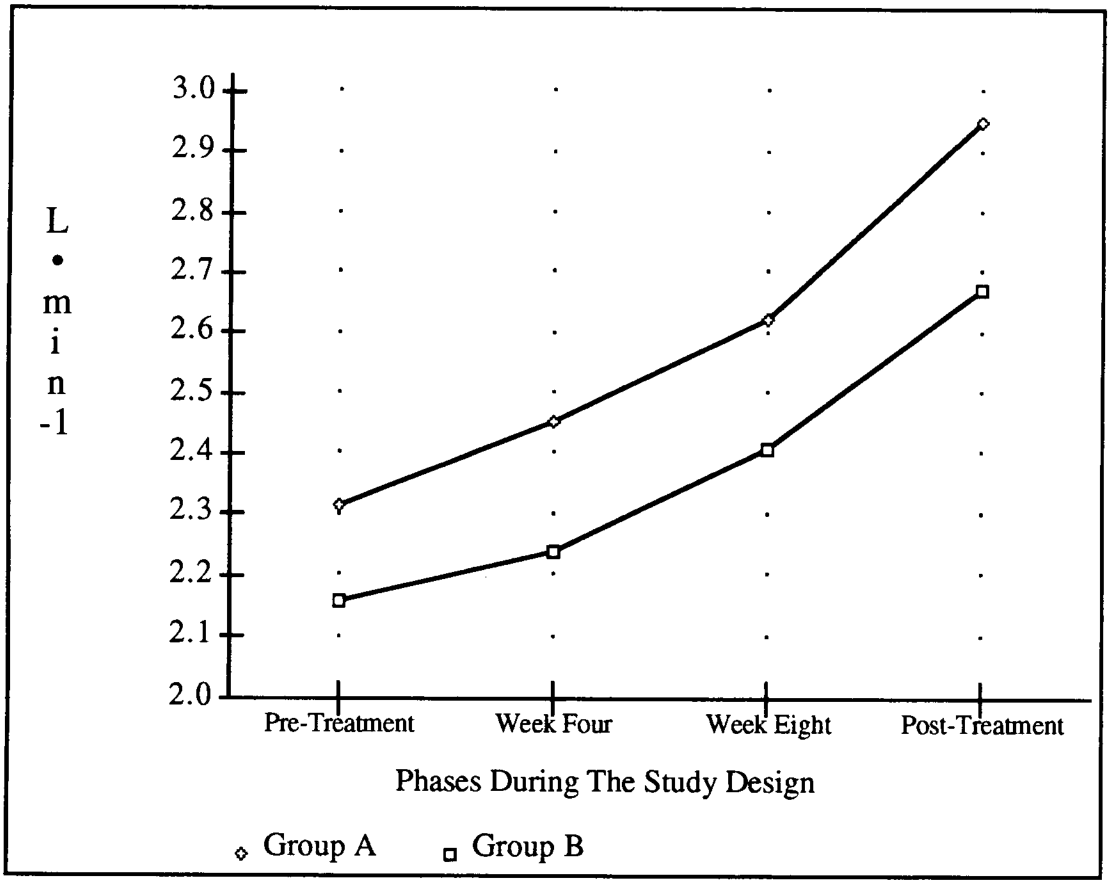

Figure 4 Mean Changes in Absolute $\dot{V}O2_{peak}$ ($L \bullet min^{-1}$) Over the Course of the Study

Group B. An unpaired t-test also did not detect a significant difference ($t(22) = 0.745$, $p > .05$) between the mean pre-treatment measures of relative $\dot{V}O_2peak$ in Group A versus Group B. The main effect of time was statistically significant ($F(3, 66) = 222.9$, $p < .001$). This was evidenced by the slope of the lines in Figure 5. A Newman-Keuls post hoc analysis showed that there was a significant difference ($p < .001$) in the mean relative $\dot{V}O_2peak$ values for Group A measured from the pre-treatment to week four, week four to week eight, and week eight to the post-treatment assessment. The same pattern of significant differences ($p < .001$) was exhibited by Group B during the week four to week eight and the week eight to the post-treatment assessment phases. There was no significant difference ($p > .05$) in the mean relative $\dot{V}O_2peak$ in Group B during the pre-treatment to the week four assessment phase . The interaction of group by time was also significantly different ($F(3, 66) = 9.1$, $p < .001$) which indicated that the change over time was different in the two groups. This too was evidenced by the difference in slopes of the two lines in Figure 5. A Newman-Keuls post hoc analysis showed that the mean post-treatment relative $\dot{V}O_2peak$ was significantly ($p < .001$) different in Group A versus Group B. Thus, when oxygen uptake was related to body weight (relative $\dot{V}O_2peak$) there was evidence to suggest that there was a significant improvement in relative $\dot{V}O_2peak$ experienced by both groups, and since groups began with non-significantly different ($p > .05$) values, there was also evidence to show that Group A improved more than Group B.

Table 10 Mean Changes in Relative $\dot{V}O_2peak$ (ml•kg-1•min-1) Over the Course of the Study

		Treatment Phase		
Group	**Pre-**	**Wk 4**	**Wk 8**	**Post-**
A	26.57	28.81 *	33.09 *	38.54 *
B	25.68	26.95 ns	29.45 *	33.69 *
Mean Difference	0.89 *	1.86 *	3.64 *	4.85 *

* indicates a statistically significant difference ($p < .05$)

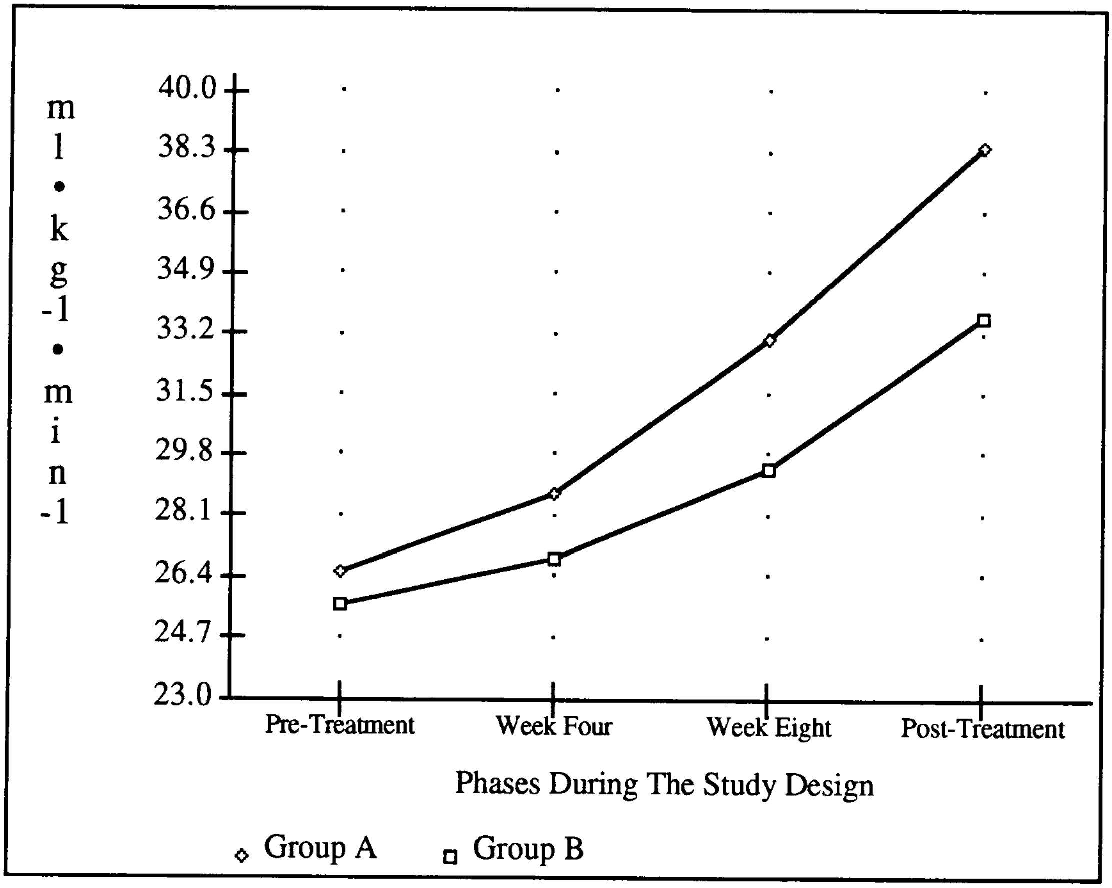

Figure 5 Mean Changes in Relative $\dot{V}O2_{peak}$ ($ml \bullet kg^{-1} \bullet min^{-1}$) Over the Course of the Study

When oxygen uptake was expressed relative to kilograms of body weight, a 12-week program of high intensity exercise, performed in one to two-minute intervals, produced more of an improvement than 12 weeks of moderate intensity exercise, performed in continuous bouts. Since Group A also lost more weight than Group B did over the 12-week training period, and since there was not a significant difference in the absolute $\dot{V}O_2peak$ changes of Group A versus Group B, the significant difference in relative $\dot{V}O_2peak$ improvements experienced by Group A could be attributed more to the changes in body weight.

Table 11 details the mean changes in REE that occurred over the course of the study. Figure 6 depicts these changes. The mean increase in REE was 503.96 kcal•m^2-1•day-1 for Group A, and 224.66 kcal•m^2-1•day-1 for Group B. This represented a 53.4 percent improvement for Group A, and a 23.6 percent improvement for Group B. The main effect of group was statistically significant ($F(1, 22) = 27.0$, $p < .001$). A Newman-Keuls post hoc analysis showed that the mean REE measured during week four, week eight, and during the post-treatment assessment was significantly different ($p < .001$) in Group A versus Group B. The mean REE measured during the pre-treatment assessment was not significantly different ($p > .05$) in Group A versus Group B. An unpaired t-test also did not detect a significant difference ($t(22) = 0.248$, $p > .05$) between the pre-treatment measures of REE in Group A versus Group B. The main effect of time was statistically significant ($F(3, 66) = 298.1$, $p < .001$). This was evidenced by the slope of the lines in Figure 6. A Newman-Keuls post hoc analysis showed that Group A experienced a statistically significant ($p < .001$) increase in the mean REE measured from the pre-treatment to the week four assessment, week four to week eight, and week eight to the post-treatment assessment. Group B also experienced a statistically significant increase in the mean REE measured from the pre-treatment to the week four assessment ($p < .05$), week four to week eight ($p < .01$), and week eight to the post-treatment assessment ($p < .001$). The interaction of group by time was also significantly different ($F(3, 66) = 43.2$, $p < .001$) which indicated that the change over time was different in the two groups. This too was evidenced by the difference in slopes of the two lines in Figure 6. Thus, there was evidence to suggest that there was a significant improvement in REE experienced by both groups, and since the two groups began with non-significantly different ($p > .05$) values, there was also evidence to show that Group A improved more than Group B.

Table 11 Mean Changes in Resting Energy Expenditure Over the Course of the Study Measured in Kilocalories per Square Meter of Body Surface Area per Day

Group	Pre-		Treatment Phase Wk 4		Wk 8		Post-	
A	943.36		1074.02	*	1210.64	*	1447.32	*
B	950.46		989.11	*	1041.63	*	1175.12	*
Mean Difference	7.10	ns	84.91	*	169.01	*	272.20	*

* indicates a statistically significant difference ($p < .05$)

It was concluded that a 12-week exercise program produced statistically significant improvements in total body weight, percent body fat, absolute $\dot{V}O2peak$, relative $\dot{V}O2peak$, and REE regardless of which format was followed. Neither group experienced a statistically significant change in FFW. There were statistically significant differences in the mean scores of the two groups measured during the pre-treatment assessment in the variables total body weight, percent body fat, and absolute $\dot{V}O2peak$. These differences were attributed to chance that resulted from the randomization process followed to determine treatment groups. There was statistical evidence to show that participants in Group A improved more than participants in Group B in the variables total body weight, percent body fat, relative $\dot{V}O2peak$, and REE. The improvement in relative $\dot{V}O2peak$ was attributed more to the changes in body weight. However, participants who exercised in intervals of one to two-minutes in duration at a high intensity for 12 weeks showed more improvement than participants who exercised in continuous bouts at a moderate intensity in the components most exercise programs list as appropriate goals .

Correlation coefficients were calculated to determine if evidence of association was present between the mean changes in the variables of total body weight, percent body fat, fat-free weight, absolute $\dot{V}O2peak$, relative $\dot{V}O2peak$, and REE. Results appear in Table 12. There were fairly significant associations between the variables in both Group A and Group B. For example, the association between total body weight and relative $\dot{V}O2peak$ was $r = -.739$ for Group A. This indicated that the individuals with greater total body weight measured lower in maximal oxygen uptake, expressed relative to kilograms of body weight, than individuals with less total body weight.

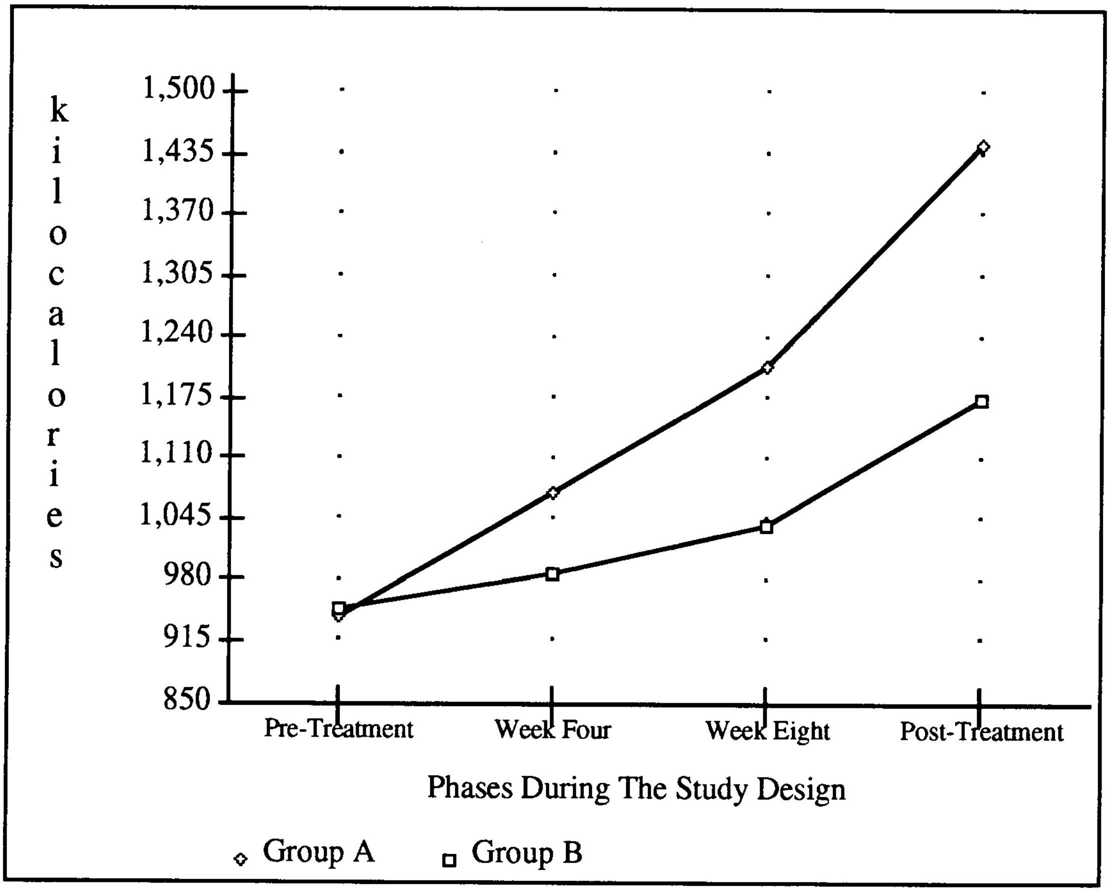

Figure 6 Mean Changes in Resting Energy Expenditure Over the Course of the Study Measured in Kilocalories per Square Meter of Body Surface Area per Day

According to Safrit (1990) a general rating of the association between variables is:

± .80 to 1.00 High
± .60 to 0.79 Moderately High
± .40 to 0.59 Moderate
± .20 to 0.39 Low
± .00 to 0.19 No Relationship (p. 66).

The degree of association between the variables total body weight and relative $\dot{V}O2peak$ was moderately high. Consequently, the coefficient of determination, or r^2, which is an indication of the shared variance between the two variables, was .546. Thus 54.6 percent of the total variance in the two variables was the result of a common factor or factors. Since total body weight was measured in kilograms and maximal oxygen uptake was expressed relative to kilograms of body weight, the interaction effect of these two variables was expected. However, the association between total body weight and relative $\dot{V}O2peak$ was r = -.421 for Group B. The coefficient of determination, r^2, was .177 or 17.7 percent. This represents a moderate association. Individuals in Group B showed more variation when their total body weight was compared to their relative maximal oxygen uptake. Further investigation into this relationship, and the relationship between the other variables compared appears in Chapter Five.

Table 12 Correlation Coefficients Between the Variables Total Body Weight (Wt), Percent Body Fat (% Fat), Fat-Free Weight (FFW), Absolute $\dot{V}O2peak$ (A $\dot{V}O2$), Relative $\dot{V}O2peak$ (R $\dot{V}O2$), and Resting Energy Expenditure (REE)

	Wt	% Fat	FFW	A $\dot{V}O2$	R $\dot{V}O2$	REE
Group A: High Intensity, Interval Training Group						
Wt						
% Fat	.377 ns					
FFW	.807 p<.001	-.241 ns				
A $\dot{V}O2$	-.305 ns	-.779 p<.01	.180 ns			
R $\dot{V}O2$	-.739 p<.01	-.752 p<.01	-.296 ns	.857 p<.001		
REE	-.549 ns	-.703 p<.01	-.123 ns	.779 p<.01	.827 p<.001	

(Table 12 continued)

	Wt	% Fat	FFW	A $\dot{V}O2$	R $\dot{V}O2$	REE
Group B: Moderate Intensity, Continuous Training Group						
Wt						
% Fat	-.205 ns					
FFW	.927 p<.001	-.557 ns				
A VO2	.152 ns	-.613 p<.05	.365 ns			
R VO2	-.421 ns	-.440 ns	-.188 ns	.828 p<.001		
REE	-.238 ns	-.519 ns	-.004 ns	.617 p<.05	.698 p<.01	

CHAPTER V

DISCUSSION AND CONCLUSIONS

The purpose of this study was to investigate the effects of a 12-week training period, during which moderate and high intensity exercise were utilized in an attempt to alter resting energy expenditure (REE) in obese, college-aged females who were also dieting. Of particular interest was the question of which form of exercise, moderate intensity performed in continuous bouts or high intensity performed in one to two-minute intervals, would produce the greatest change in REE.

Twenty-four female subjects with a mean age of 20.8 years were randomly assigned to one of two exercise groups. Group A met three times per week and performed stationary cycling in an interval format lasting between one and two minutes per interval until a pre-determined workload had been achieved. The exercise intensity was at a heart-rate level corresponding to 85 percent of $\dot{V}$O2peak. Group B also met three times per week and performed stationary cycling in a continuous bout until a pre-determined workload had been achieved. The exercise intensity for Group B was at a heart-rate level corresponding to 60 percent of $\dot{V}$O2peak. Both groups completed the same quantity of exercise in each exercise session, measured in kilogram meters (kgm), and both groups trained for 12 weeks. Subjects were also monitored two or three times per minute to insure that target heart rates were achieved and maintained over the course of the treatment.

The treatment design was divided into three, four-week phases. Maximal graded exercise tests (GXT's) were performed at the conclusion of each phase so that adjustments could be made to the training heart rate to insure that the subjects continued to train at the target intensities.

Both groups experienced statistically significant increases in REE over the course of the 12-week treatment. Group A experienced a mean increase of 503.96 kcal, and Group B experienced a mean increase of 224.66 kcal in REE. Table 13 presents the changes both groups experienced over the course of the study. During each four-week phase, the changes in REE experienced by both groups were also statistically significant. Thus, the mean REE for Group A increased significantly from each previous assessment. The same pattern was demonstrated by the participants in Group B. At the beginning of the study the mean REE of Group A was not statistically different ($p > .05$) from the mean REE of Group B. The mean REE of Group A was 943.36 kcal•m^2-1•day-1 versus 950.46 kcal•m^2-1•day-1 for Group B. There were statistically significant differences in the mean

REE of Group A versus Group B measured during the fourth week, eighth week, and post-treatment assessments. Results of a Newman-Keuls post hoc analysis appear in Table 14. In all three assessments, however, the mean REE of Group A was greater than the mean REE of Group B. In this 12-week program, participants who exercised using high intensity intervals experienced a 2.24-fold increase in REE versus those who exercised using moderate intensity, continuous training. Thus, in a population of obese, sedentary females, evidence suggests that interval training, using one- to two-minute intervals at a high intensity, will produce more of an elevation in the REE than continuous bouts of exercise performed at a moderate intensity.

Table 13 Mean Increase in REE by Phase Over the Course of the Study Measured in Kilocalories per Square Meter of Body Surface Area per Day

Treatment Phase	**Group A**	**Group B**	**Difference**	
Pre-Treatment to Week Four	130.66	38.65	92.01	*
Week Four to Week Eight	136.63	52.52	84.11	*
Week Eight to Post-Treatment	236.68	133.50	103.18	*
Pre- to Post-Treatment	503.96	224.66	279.30	*

* denotes a significant difference ($p < .05$)

Table 14 Newman-Keuls Post Hoc Test for Significant Difference in REE Between Group A and Group B Over the Course of the Study

REE		{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}
	mean	943	1074	1211	1447	951	989	1042	1175
A 1	{1}								
A 2	{2}	.0001							
A 3	{3}	.0001	.0001						
A 4	{4}	.0001	.0001	.0001					
B 1	{5}	.6965	.0001	.0001	.0001				
B 2	{6}	.0368	.0001	.0001	.0001	.0367			
B 3	{7}	.0001	.0785	.0001	.0001	.0001	.0052		
B 4	{8}	.0001	.0001	.0542	.0001	.0001	.0001	.0001	

The results of this investigation conflict with those reported by Magnaye, Chad, & Drinkwater (1993). They looked at single bouts of exercise at intensity levels of 40, 50, 60, and 70 percent of maximal oxygen uptake ($\dot{V}O2max$) performed in 30-minute continuous sessions. They measured post-exercise oxygen consumption in mildly to moderately obese men and women for three hours following each exercise bout and recorded the greatest post-exercise energy expenditure after the session performed at 40 percent of $\dot{V}O2max$. Magnaye and co-workers concluded that: "mild-moderately obese individuals can exercise at a safe, moderate level of intensity and gain greater benefits in terms of post-exercise energy expenditure than at higher exercise intensity levels (p. S101)." But there was no mention of the number of subjects, whether they were dieting, and they did not report how fit their subjects were. Also, since they did not report any long-term effects of a training program on these same subjects it is difficult to compare the studies and discuss applications based on the results of each.

Lennon and associates (1985) were able to show a statistically significant increase in the REE of obese, dieting subjects who exercised at a moderate intensity level. One group exercised daily on their own and experienced a mean increase of ten percent in REE after 12 weeks. A second group exercised every other day in supervised sessions and experienced a mean increase of four percent in REE after 12 weeks. The percent change in REE during this investigation is reported in Table 15. Over the course of this study Group A experienced a 53.4 percent increase in REE and Group B experienced a 23.6 percent increase in REE after 12 weeks. Both values far exceed the changes reported by Lennon and associates. This may be due, in part, to the fact that subjects in this investigation began with very low REE values. Mean pre-treatment REE values for all twenty-four subjects was 946.91 kcal. In comparison, the mean pre-treatment REE reported by Lennon et al. was 1321 kcal. Lennon's subjects began with a mean REE 374 kcal higher (or 39.5 percent greater) than subjects in this investigation.

Table 15 Percent Change in the Mean REE Over the Course of the Study

Treatment Phase	**Group A**	**Group B**	**Difference**
Pre-Treatment to Week Four	13.85%	4.07%	9.78%
Week Four to Week Eight	12.72%	5.31%	7.41%
Week Eight to Post-Treatment	19.55%	12.82%	6.73%
Pre- to Post-Treatment	53.42%	23.64%	29.78%

The mean basal energy expenditure predicted from body surface area, age, and gender for the subjects in this investigation was 1649.59 kcal prior to the start of the treatment. McArdle et al. (1991) reported:

> In most instances, BEE values measured under controlled conditions are only slightly lower than REE values measured three to four hours following a light meal. For our purposes, the terms basal and resting energy expenditure rates are used interchangeably (p. 158).

If this situation was true in the population studied in this investigation, then either the prediction technique for estimating BEE presented by McArdle et al. is invalid or the subjects' mean measured REE was significantly below "normal." The difference in predicted BEE and measured REE was 702.68 kcal per square meter per day or 74.2 percent. McArdle et al. (1991) reported the BEE values estimated from body surface area, age, and gender curves ". . . was within 10 percent of the actual value obtained from measurements under strict laboratory conditions" (p. 160).

The degree to which chronic dieting lowers REE in relation to predicted BEE has never been reported in the literature. Several authors have reported that severe caloric restriction could lead to a lower than normal REE (Franklin, 1984; Molé et al., 1989; Garrow, 1978; ACSM, 1983; Pollock & Wilmore, 1990; Brown, 1992; McGlynn, 1993; Mullen, Gold, Belcastro, & McDermott, 1993; and Williams, 1990); none of these studies, however, compared REE to predicted BEE. They simply stated that the REE rate measured during their studies was lower after a period of dieting than what it was when their investigation began.

One of the classical studies involving changes in the metabolism as a result of dietary restriction was performed by Benedict (1915). One subject fasted for 31 days inside an indirect calorimetry chamber. Continuous measurements were made of oxygen consumption and carbon dioxide production. Daily measurements were also made of nitrogen balance and urinary constituents. Total energy expenditure, which included physical activity inside the chamber, decreased from 1770 kcal to 1250 kcal by the eighteenth day. This constituted a 29.4 percent reduction in total energy expenditure. There was no statistically significant difference in energy expenditure rates for the remaining 13 days. In the study reported by Benedict, only water was ingested during the investigation. Even though this form of dietary restriction was not practiced by any of the subjects participating in this study, the reduction in energy expenditure experienced in fasting was still far less than that of the difference between predicted BEE versus measured REE demonstrated by the subjects: 29.4 percent fasting versus 74.2 percent differences in measured REE versus predicted BEE.

Without knowing the degree of the representation of obese subjects sampled in the studies that created the prediction techniques outlined by McArdle et al. (1991) to estimate BEE from body surface area, age, and gender, it is difficult to state that the technique is invalid. However, since many authors have reported "normal" REE values for individuals of the same age and gender as those studied in this investigation well above those measured during the pre-treatment assessment, it is easier to conclude that the subjects investigated in this study had "abnormal" REE values before the treatment began. A summary of REE values for female subjects between the ages of 19 and 24 years, is reported by author in Table 16. More studies need to be done using obese subjects to see if the prediction technique to estimate BEE outlined by McArdle et al. (1991) is indeed valid for obese individuals. In the meantime, it would be helpful if texts utilizing the prediction technique would describe the populations in which estimations have been proven to be valid.

Table 16 Reported Average Resting Energy Expenditure Values for College-Aged Females by Author

Author	**Average REE**
Althoff, Svoboda, & Girdano (1992)	1728
Bursztein et al., (1989)	1562
Griffiths et al., (1990)	1682
Hockey (1993)	1740
Lennon et al., (1985)	1321 *
McGlynn (1993)	1680

* a study which measured obese subjects

The daily dietary deficit recommended by the American College of Sports Medicine (1983) in their position paper entitled, "Proper and Improper Weight Loss Programs," was 200 to 300 kilocalories per day. Three consecutive one-day dietary intake records were collected and analyzed for each subject each week to insure that the subjects were dieting. Average daily caloric deficits were calculated for each subject from the pre-treatment assessment, the week-four collection, and the week-eight collection. The mean daily dietary deficits appear in Table 17. Subjects in this study were successful in maintaining a 200 to 300 kcal daily dietary deficit over the course of the study.

Table 17 Mean Daily Dietary Deficit Over the Course of the Study Measured in Kilocalories per Square Meter of Body Surface Area per Day

Treatment Phase	**Group A**	**Group B**
Pre-Treatment	265.38	306.85
Week Four	281.20	202.91
Week Eight	302.26	293.72

The dieting practices followed by the participants during the treatment did not appear to be describable as "severe caloric restriction." Molé and co-workers (1989) were able to detect a statistically significant depression in REE after three weeks of dieting with caloric intakes below 1,000 kilocalories per day. Pre-treatment analyses of food intake records showed a mean caloric intake of 1,063.58 kilocalories for Group A, and 1,026.92 kilocalories for Group B. Only five individuals had average daily caloric intakes below 1,000 kilocalories per day. Caloric intakes for each subject appear in Appendix D for the pre-treatment collection, Appendix J for the week-four collection, and Appendix M for the week-eight collection. Consequently, REE values recorded during the treatment should not have been influenced by the dieting. One explanation is that several years of chronic dieting may be responsible for a lowering REE. To date, however, there have been no longitudinal studies which have followed dieters for more than a year and which have included REE as one of the parameters regularly monitored.

The results from this investigation show that following 12 weeks of high intensity, interval training it was possible for Group A to bring REE levels back up to values approximating those which were predicted based on body surface area, age, and gender. The mean post-treatment measured REE for Group A was 1447.32 kcal•m^2-1•day-1. The mean predicted BEE for the same group was 1511.67 kcal•m^2-1•day-1. The difference was still 64.35 kcal•m^2-1•day-1, but this difference was much more realistic than the 706 kcal•m^2-1•day-1 mean difference in predicted BEE to measured REE the subjects from Group A began the treatment with. It makes sense to an individual who is trying to lose weight that the more REE can contribute to the energy out portion of the negative balance equation, the more likely the person is going to succeed in losing weight. The reader is reminded that in Chapter One a negative caloric balance was explained as the goal for weight loss; to create a negative caloric balance one must have more energy expenditure than energy intake.

To more clearly understand how the results of this study should be interpreted, specific characteristics of the population studied need further discussion. The first criteria for subject selection of the population studied was that they were obese. Obesity has been difficult to quantify. The American College of Sports Medicine (1991) defined obesity as a situation in which the risk of disease is increased. The variable percent body fat has been used as an indicator of obesity; however, the value utilized to categorize people as obese is highly controversial. Authors of three prominent exercise physiology textbooks (Pollock & Wilmore, 1990; Brooks & Fahey, 1985; and McArdle et al., 1991) argue that there is more to obesity than a specific percent body fat. Several authors (Heyward, 1991; Brown, 1992; McGlynn, 1993; Mullen, Gold, Belcastro, & McDermott, 1993; and Williams, 1990) who have written general health and fitness texts, targeted toward a college-aged audience, labeled obesity in women as a percent body fat greater than 30 percent. Percent body fat values were collected on the subjects participating in this study primarily to quantify fat loss. Group A began the treatment with a statistically higher ($p < .001$) percent body fat in comparison with Group B. Pre-treatment and post-treatment percent body fat values appear in Table 18.

Table 18 Mean Percent Body Fat Values Measured Pre- and Post-Treatment

Treatment Phase	**Group A**	**Group B**	**Difference**
Pre-Treatment	37.28	34.07	3.21 *
Post-Treatment	30.18	31.07	-.89 ns
Change	-7.10 *	-3.00 *	4.10 *

* Denotes a statistically significant ($p < .05$) difference

Over the course of the treatment, participants in Group A experienced a mean decrease in percent body fat of 7.1 percent. Participants in Group B experienced a mean decrease of 3.0 percent in percent body fat. While both groups experienced a significant decrease, there was no significant difference in the percent body fat measured in the post-treatment assessment in Group A versus Group B. Since Group A began the treatment with a higher percent body fat, the change in percent body fat experienced by Group A was significantly more than the change experienced by Group B. This was evidenced by the main effect of time by group ($F(1, 22) = 27.2$, $p < .001$). In relative terms, Group A experienced a 19.0 percent reduction and Group B experienced an 8.8 percent reduction in percent body fat. While fat loss was not the focus of this investigation, it should be mentioned that both groups did experience a significant reduction in percent body fat.

It has been suggested that REE should be standardized to a suitable index of body size. Cunningham (1980), Keys, Taylor, and Grande (1973), Ravussin, Lillioja, Anderson, Christin, and Bogardus (1986), and Poehlman, Melby, and Badylak (1990) have suggested fat-free weight (FFW) as the appropriate reference unit. Poehlman et al. reported a significant association ($r = .57$, $p < .01$) between FFW and REE. Poehlman and associates also reviewed the studies by Cunningham (1980), Keys, Taylor, and Grande (1973); and Ravussin et al., (1986) and attributed their lower order correlation between FFW and REE as reflective of the homogeneity of their subjects with respect to FFW. In comparison, correlation coefficients between FFW and REE ranged from .70 to .84 in the other studies reviewed by Poehlman, Melby, and Badylak. They also reported that they measured a wide variation in REE within the group of older sedentary men. One conclusion drawn from the investigation reported by Poehlman, Melby, and Badylak (1990) was that "a sedentary lifestyle in older men may be associated with a lower REE, independent of FFW and percent body fat, relative to younger men and older men who exercise regularly (p. B54)."

The correlation coefficients found during this investigation between the changes in percent body fat and the changes in REE were $r = -.703$, $p < .01$ for Group A and $r = -.519$, $p > .05$ for Group B. These results are very similar with those reported by Poehlman, Melby, and Badylak (1990), Cunningham (1980), Keys, Taylor, and Grande (1973), and Ravussin et al., (1986). There appears to be a significant association between percent body fat and REE and individuals with a lower percent body fat tend to have a higher REE.

The main effect of time was not statistically significant ($F(1, 22) = 2.4$, $p > .05$) in FFW over the course of the study and the interaction of group by time was also not statistically significant ($F(1, 22) = 0.3$, $p > .05$) between Group A and Group B. Correlation coefficients were determined between the changes in FFW and REE for both Group A and Group B from the pre- and post-treatment assessments. The correlation coefficient determined for Group A was $r = -.123$; $p > .05$. The correlation coefficient determined for Group B was $r = -.004$; $p > .05$. Since previous investigators (Poehlman, Melby, & Badylak, 1990; Cunningham, 1980; Keys, Taylor, & Grande, 1973; and Ravussin et al., 1986) all advocated the inclusion of FFW into the standardization process, a backward stepwise multiple regression model was constructed with REE as the dependent variable and percent body fat and FFW as independent variables. Summary statistics for this model appear in Appendix V, Section 5. With both variables included the adjusted coefficient of determination (adjusted r^2) for Group A was .546 and for Group B was .336. With FFW removed from the model, the adjusted coefficient of determination was .472 for Group A and .236 for Group B . Consequently, FFW did improve the predictability of REE. Percent body fat alone, however, accounted for most of the shared variance.

Consequently, in a population of individuals who have a large percentage of body fat, standardization of REE by some body composition variable does seem appropriate. Based on the results of this investigation, future investigations involving assessment of REE should also include a relative REE variable. Poehlman, Melby, and Badylak (1990) suggested adjustment based from analysis of covariance with FFW and percent body fat as covariates. Cunningham (1980), Keys, Taylor, and Grande (1973), and Ravussin et al., (1986) all reported a relative REE value expressed as kilocalories per minute per kilogram of FFW. Since the regression model developed from this investigation only showed a coefficient of determination of .015 for Group A and .000014 for Group B when FFW was regressed against REE, more work needs to be done before REE is adjusted to FFW alone in a population of obese individuals. Thus, further investigation into the association between body composition and REE is suggested.

Total body weight was one of the variables monitored over the course of the study. It was necessary for the calculation of predicted BEE, which was used to monitor the subjects' dietary deficit. Total body weight was also used to determine relative $\dot{V}O2peak$ upon which the exercise training intensities were based. Total body weight was not, however, intended to be utilized as a significant indicator of treatment success or failure. From the subjects' point of view, total body weight and the weight loss experienced over the course of the study, were perhaps the most important aspects of the study. After the conclusion of the first four-week phase, there were no missed exercise sessions by participants of either group. Every subject expressed frequently that their greatest motivation for continued participation in the study was the weight loss experienced over the course of the study. One of the concerns this investigator had was that the subjects would get together on their own to exercise so that weight loss would be even greater. Subjects were routinely questioned about their outside activities, and no one reported extracurricular training activity. However, the possibility of unreported training should be viewed as a limitation.

The mean weight loss experienced by Group A over the course of the study was 10.51 kilograms (23.12 lbs). This may not appear to be a large amount of weight loss in a population where the mean pre-treatment total body weight was 87.63 kilograms (193 lbs), but this also was a population that reported a five to ten year history of trying to lose weight. All subjects from both groups reported gaining between five to ten pounds (2.27 to 4.54 kgs) over the last year, and many (11) reported gaining close to 20 pounds (9.09 kgs).

In comparison, the mean weight loss reported by Lennon and co-workers (1985) during their 12-week treatment was 6.32 pounds (2.87 kgs) for the group of mildly to moderately obese men and women that exercised every day on their own and experienced a ten percent increase in REE. The mean weight loss for the group that exercised every other day in supervised sessions was 4.77 pounds (2.17 kgs), and they experienced a four percent increase in REE. Participants in Group B exercised closer to the intensity used by Lennon et al. but experienced a 1.5-fold greater weight loss than Lennon's group. Participants in Lennon's group also exercised daily, while participants from Group B exercised three days per week.

One of the major differences in the treatment administered to each group was the exercise intensity. Group A performed exercise which corresponded to 85 percent of $\dot{V}O2peak$ while Group B performed exercise at a level of 60 percent of $\dot{V}O2peak$. Both groups were monitored during the treatment sessions by heart rate and matched to target heart rates achieved during maximal GXT's. The GXT's were conducted during the pre-treatment assessment, during week four, during week eight, and during a post-treatment assessment. It was believed that target heart rates would change once improvement in aerobic fitness was realized by the participants. Both groups experienced significant improvement in VO2max over the course of the study in both absolute and relative terms.

The American College of Sports Medicine (1991) advocated exercise intensities of 40 to 85 percent of $\dot{V}O2max$ for durations of 15 to 60 minutes and recommended that the exercise be performed by large muscle groups in a continuous, rhythmic fashion to improve aerobic fitness. Thus, Group B should have experienced a more significant improvement than Group A. However, Group A, which exercised in one to two-minute intervals, at an exercise intensity corresponding to 85 percent of $\dot{V}O2peak$ experienced a significantly ($p < .001$) greater improvement in absolute $\dot{V}O2peak$ and a significantly ($p < .001$) greater improvement in relative $\dot{V}O2peak$ than Group B.

It was not the intention of this study to investigate which form of exercise would produce the greatest improvement in $\dot{V}O2peak$. The purpose was to see which form of exercise would produce the greatest change in REE. However, many investigators have linked REE to $\dot{V}O2max$. Poehlman, Melby, and Badylak (1990), Poehlman et al. (1989), Poehlman, Melby, and Badylak (1988), Tremblay, Fontaine, and Nadeau (1985), and Tremblay et al. (1986) reported that young, endurance trained males had a higher REE than matched sedentary subjects. Poehlman et al. (1989) compared a wide range of fitness levels ($\dot{V}O2max$ from 40 to 80 ml•kg-1•min-1) and reported a significant positive relationship ($r = .77$, $p < .01$) between $\dot{V}O2max$ and REE. Lennon and co-workers (1985) investigated mildly to moderately obese men and women and reported a significant relationship between improving $\dot{V}O2max$ and elevating REE after 12 weeks of training. Their reported correlation coefficient, however, was $r = .307$, $p < .01$. According to Safrit (1990), this represents a low association. The correlation coefficients between changes in absolute $\dot{V}O2peak$ and changes in REE for this study were $r = .779$, $p < .01$ for Group A and $r = .617$, $p < .05$ for Group B. The correlation coefficients between changes in relative $\dot{V}O2peak$ and changes in REE were $r = .827$, $p < .001$ and $r = .698$, $p < .01$ for Groups A and B, respectively. These associations, according to Safrit (1990), represent moderately high and high degrees of association between the variables $\dot{V}O2peak$ and REE. Consequently, when individuals increased their aerobic capacity, as evidenced by increases in absolute and relative $\dot{V}O2peak$, they also had higher REE values than before they started exercising.

To further evaluate the association between the variables tested another backward stepwise multiple regression model was developed using total body weight, percent body fat, absolute $\dot{V}O2peak$, relative $\dot{V}O2peak$, and FFW as predictors of REE. The combined adjusted coefficient of determination for this model was .644 for Group A and .424 for Group B. When absolute $\dot{V}O2peak$ was regressed alone against REE the adjusted coefficient of determination was .589 for Group A and .353 for Group B. When relative $\dot{V}O2peak$ was regressed alone against REE the adjusted coefficient of determination was .670 for Group A and .463 for Group B. Summary statistics for this model appear in Appendix V, Section 5. Hence, the best single predictor of REE out of the variables tested, in both Group A and Group B, was relative $\dot{V}O2peak$, which demonstrated the highest coefficient of determination.

For this population, there appeared to be strong evidence suggesting that the association between REE and the capacity for aerobic fitness, measured by absolute and relative $\dot{V}O2peak$, was strongly linked. This association was strongest with Group A, who also had the highest absolute and relative $\dot{V}O2peak$ scores. Poehlman et al. (1989) reported higher correlations between REE and $\dot{V}O2max$ with highly trained endurance athletes than in comparisons which used sedentary subjects. However, any correlation will be higher when two variables are strongly related and the subjects are very homogeneous as compared to subjects who have a wide range in scores. In this population, Group A also lost the most weight. Consequently, with the accompanying loss of body weight, $\dot{V}O2$peak expressed relative to kilograms of body weight, showed the highest association to REE ($r = .827$, $p < .001$). With 11 degrees of freedom, this represented a very strong association. Therefore, in a population of obese, college-aged females, a program of exercise which improves maximal oxygen uptake should also elevate REE.

The mechanism behind the linkage of REE to $\dot{V}O2$peak is fairly complex. Bahr, Hansson, and Sejersted (1990) concluded that an increase in the fatty acid mobilization-oxidation cycling explained a substantial portion of the enhanced REE following exercise. They compared excess post-exercise oxygen consumption (EPOC) in trained versus untrained subjects and found the trained subjects displayed higher EPOC values for longer periods of time following exercise than the untrained subjects. The same conclusions were made by Tremblay, Fontaine, and Nadeau (1985) and Poehlman, Melby, and Badylak (1988). This implies that the increases in REE and in lipid utilization observed in trained subjects are closely linked and the underlying mechanism is likely to be similar. However, the subjects from Group A, who exercised in high intensity intervals of one to two minutes in duration, experienced more of a long-term adaptation in both aerobic exercise capacity, measured by $\dot{V}O2$peak, and REE. Since exercise of this type does not favor lipid metabolism (McArdle et al., 1991; Pollock & Wilmore, 1990; Gore & Withers, 1990; Bahr, Hansson, and Sejersted, 1990; and Bahr, Grønnerød, & Sejersted, 1992), it does not follow that exercise which relies very little on lipid sources could produce significant improvements in the mobilization and utilization of lipid fuel sources. McArdle et al. (1991) summarized the metabolic adaptations in anaerobic function that accompanied strenuous physical exercise by stating:

> In keeping with the concept of specificity of training, activities that demand a high level of anaerobic metabolism bring about specific changes in the immediate and short-term energy systems, without a concomitant increase in aerobic functions (p 428).

Interpretation of this statement suggests that anaerobic exercise would have little effect on the aerobic energy system, which primarily involves the mobilization and utilization of lipid fuel sources. However, other investigators (Gaesser & Rich, 1984; Daniels & Scardinia, 1984; and Sharkey, 1970) have also demonstrated that $\dot{V}O2$peak can be raised following treatment programs of high intensity exercise performed in an interval format.

Even though lipid mobilization and utilization have been strongly linked to elevations in $\dot{V}O2peak$ and REE (Poehlman et al. 1985; Bahr et al. 1990; Tremblay et al. 1985; and Poehlman et al. 1988) there must be other mechanisms involved. It was unfortunate that respiratory exchange ratios (R-values) were only collected during maximal GXT's and not during the treatment sessions. R-values would have enabled estimation of the percentage of total fuel utilization from lipid sources. However, heart rates were recorded during the treatment sessions. Target heart rates of plus or minus three beats per minute were maintained during all of the treatment applications. Subjects in Group A maintained target heart rate intensities in excess of 90 percent of maximal heart rates determined from maximal GXT's. According to Gore and Withers (1990), Bahr et al. (1990), and Bahr et al. (1992), exercise intensities performed at levels which elicited a heart rate at or above 90 percent of maximal heart rate produced very high R-values. Bahr et al. (1992) reported mean R-values in excess of 1.2 in male endurance athletes following two-minute intervals of very high intensity exercise. R-values at or slightly above 1.0 suggest very little, if any, contribution to the general energy pool from lipid sources (McArdle et al., 1991). Consequently, since the heart rates achieved by subjects in Group A were greater than 90 percent of maximal heart rate, an assumption could be made that while the exercise was being performed by subjects in Group A, mobilization and utilization of lipid fuel sources was minimal. Therefore, any long-term improvement in the ability to mobilize and utilize lipid fuel sources achieved by Group A was the result of a different mechanism(s) than that achieved by Group B. A suggestion for future investigation is to repeat the treatment application, especially the high intensity interval format, collect expired gases for analysis to determine R-values, and monitor the R-values for change.

It has been suggested that the metabolic adaptations that take place as a result of exercise training are mediated by an increased tonus of the sympathetic nervous system. Richter, Christensen, Ploug, and Galbo (1984) showed an *in vitro* response in dogs that oxygen consumption was enhanced by adrenaline in a postexercise state. Poehlman and Danforth (1991) aerobically trained older men for eight weeks and found a strong association between elevated REE and the appearance of noradrenaline in the blood. Tremblay and co-workers (1990) administered adrenaline to trained and untrained male subjects and found that oxygen uptake was enhanced more in the trained individuals. They also reported, however, that even the untrained subjects responded favorably to the adrenaline in terms of improved oxygen uptake. Bahr, Hasson, and Sejersted (1990) concluded that the increase in REE due to EPOC was due to an increase in triglyceride and fatty acid cycling which was mediated by an increased release and responsiveness to catecholamines after exercise.

Tremblay, Coveney, Despres, Nadeau, and Prud'homme (1992) compared trained and untrained males after partial blockade of ß-adrenergic receptors. They administered propranolol prior to a four-hour analysis of expired gases and demonstrated that the differences in REE and lipid oxidation rates between the trained and untrained individuals were abolished when the ß-adrenergic receptors were partially blocked. They concluded that ß-adrenergic stimulation was at least partially responsible for an increased REE and lipid utilization in trained subjects. Tremblay and associates also pointed out that their studies presented new evidence that there was a dissociation between the metabolic and cardiorespiratory adaptation to endurance exercise training. This was interpreted to mean that even though metabolic adaptations and/or cardiorespiratory adaptations have taken place as the result of exercise training, without sympathetic nervous system stimulation, the adaptations will not maintain the elevated REE and increased lipid utilization.

Group A experienced greater increases in REE and $\dot{V}O2peak$ than Group B. If metabolic and cardiorespiratory adaptations are mediated by sympathetic nervous system tone, then perhaps the reason Group A experienced the most improvement in REE and $\dot{V}O2peak$ is that high intensity exercise performed in short intervals elicits more of a sympathetic nervous system response than does moderate intensity exercise performed in continuous bouts. In order to elevate the heart rate above a resting rate, sympathetic nervous system stimulation is required. In addition, catecholamines are released and sensitivity to catecholamines is enhanced. Simple deduction suggests that if sympathetic nervous system stimulation mediates metabolic and cardiorespiratory adaptation, then more stimulation will produce more adaptation.

The exercise intensity component of the formula used by exercise scientists to quantify physical activity has received much attention in the literature. The guidelines first promoted by The American College of Sports Medicine (ACSM) in 1977 recommended an exercise intensity of 60 to 80 percent of $\dot{V}O2max$ to improve cardiorespiratory fitness. In 1984, ACSM guidelines recommended an exercise intensity of 60 to 85 percent of $\dot{V}O2max$ to improve cardiorespiratory fitness. In 1990 the exercise intensity recommended in an ACSM position paper entitled "The Recommended Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory and Muscular Fitness in Healthy Adults" was 50 to 85 percent of $\dot{V}O2max$. The most recent ACSM guidelines (1991) advocated bouts of continuous activity between 15 and 60 minutes in duration, performed at an intensity that elicits a heart rate response between 40 and 85 percent $\dot{V}O2max$, three to six times per week as guidelines to improve physical fitness, in general, and cardiorespiratory endurance, in particular. The general trend has been a lowering of the exercise intensity. Steven Blair, who is Director of Epidemiology at the Institute for Aerobics Research in Dallas, has published over 100 papers in the scientific literature on the association between health and life-style, with a specific emphasis on exercise, physical fitness and chronic disease. Dr. Blair (1991) contended that the group of people who stand the most to gain from starting a regular exercise program are those who fall in the lowest category of physical fitness. His suggestion for beginning an exercise program was:

> Think about how you can build a two-minute walk into your day. List when you plan to take the walking break, and how many times a day you will do this initially. My suggestion is that you initially plan on three to five two-minute walks a day, but you should make up your own mind. Be realistic. It is more important at this stage to develop a feasible plan and to be successful than it is to get a lot of exercise (p. 20).

Justifications given by Dr. Blair included insuring success and participant safety. Thus, if Dr. Blair were to advise the individuals who participated in this investigation how to begin an exercise program, it would be fair to predict that high intensity exercise, performed in short intervals, would not be recommended.

It has long been thought that high intensity exercise increases the risk of injury. Magnaye, Chad, and Drinkwater (1993) concluded that high intensity exercise was unsafe. Nordheim and Vøllestad (1990) demonstrated very high levels of muscle lactate following two-minute intervals of downhill treadmill running and reported the subjects displayed severe muscle soreness following the training bouts. Contemporary authors of texts which included a chapter in how to begin an exercise program (McGlynn, 1993; Brown, 1992; Mullen, Gold, Belcastro, & McDermott, 1993; Hockey, 1993; Althoff, Svoboda, & Girdano, 1992; Allsen, Harrison, & Vance, 1993; Williams, 1990; and Prentice, 1991) warned against exercising too hard for fear of injury or feelings of discomfort associated with high intensity exercise.

There were no injuries sustained during the performance of the high intensity exercise during this study. This may have been due to the fact that the exercise performed was non-weight bearing. As a group, subjects in Group A appeared to have more fun than those in Group B. The treatment sessions Group A performed were always loud and showed much more evidence of group interaction than those performed by Group B. Even though the subjects were not informed of their progress over the course of the study and there were no group scores given to indicate which group was doing better, participants in Group A commented several times over the course of the study that "they could feel the changes taking place." Participants in Group B reported that they used body weight and how their clothes fit as primary indicators that progress was being made. After the treatment sessions were concluded many participants from Group B rated the treatment sessions as "boring" and "necessary to see results." In comparison, many participants from Group A rated the treatment sessions as "exciting" and "fun." Appendix U presents the results of a post-treatment assessment of exercise sessions questionnaire.

Conclusions

In a population of obese college-aged women who were dieting, a 12-week exercise training program produced significant:

- decreases in the mean total body weight,
- decreases in the mean percent body fat,
- increases in the mean absolute $\dot{V}O_2$peak,
- increases in the mean relative $\dot{V}O_2$peak, and
- increases in the mean resting energy expenditure.

There was no significant change in the mean fat-free weight over the course of the treatment. These changes were statistically significant for subjects who participated in high intensity exercise performed in one- to two-minute intervals (Group A), and for subjects who participated in moderate intensity exercise performed in continuous bouts (Group B). During this investigation, the mean values for the participants from Group A were significantly less than those for the participants from Group B in total body weight and percent body fat. The mean values for the participants from Group A were significantly greater than those for the participants from Group B in relative $\dot{V}O_2$peak and REE. There was no statistically significant difference in the increase in the mean absolute $\dot{V}O_2$peak for Group A versus Group B. Thus, high intensity exercise performed in intervals of one to two minutes in duration produced:

- a greater weight loss,
- a greater improvement in percent body fat,
- a greater increase in aerobic capacity, and
- a greater increase in the number of calories spent by the body during rest.

It was concluded that high intensity exercise, performed in one- to two-minute intervals will also produce substantial improvement in the same parameters listed traditionally as appropriate goals of most aerobic exercise programs. When participants are instructed how to accurately monitor their exercise intensity and how to distinguish between fatigue resulting from being out-of-breath versus fatigue resulting from muscle pain, high intensity exercise can also be safe. This study will hopefully encourage investigators to try new and innovative techniques to help people who are trying to lose weight. It is the opinion of the author that more research is needed which utilize populations of sedentary, obese individuals. The magnitude of the changes experienced by both groups over the course of 12 weeks suggest that the role of exercise training should be promoted in the literature as more than a vehicle to maintian weight loss.

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APPENDICES

Appendix A <u>Subject Consent</u>

It has been explained to me that the purpose of this study is to evaluate the role of physical exercise in changing resting energy expenditure. Resting energy expenditure represents a unit of measurement which quantifies how much energy the human body uses to maintain a resting state. Previous studies have shown that people who are unfit and people who have used severe dietary restriction alone as a means to lose weight have lower resting energy expenditure values in comparison to people who exercise regularly and eat a normal diet. Current knowledge suggests that the best intensity to perform exercise when the intent is to improve cardiorespiratory function is between 40 and 85 percent of maximal capacity. This investigation wishes to compare changes in resting energy expenditure after twelve weeks of training at either 60 or 85 percent of maximal capacity intensities.

I have been invited by Art W. Siemann to participate in this training study. It has been explained to me that I will be measured on four separate occasions. Each measurement collection will follow the same protocol and will include determination of percent body fat using underwater weighing techniques, measurement of resting energy expenditure using a metabolic cart, and determination of maximal exercise capacity using a bicycle ergometer, metabolic cart, and an ECG to monitor heart rate. I have seen demonstrations of the techniques involved in these tests in my Personalized Health and Fitness class and I understand the procedures involved.

I have been selected because I am healthy and have no history of medical conditions which would indicate that I should not participate in a vigorous exercise program. Prior to any preliminary testing, I understand that I will be asked to complete a health and activity questionnaire.

I understand that I will be expected to attend the exercise sessions three times a week for twelve weeks. It has been explained to me that these exercise sessions will require approximately 30 to 40 minutes to complete and that they will require me to work very hard. Exercise will be performed on stationary bicycles and my heart rate will be closely monitored. I understand that exercise places physical stress on me. Any symptoms of an abnormal response by my body to the exercise, such as chest pain, excessive shortness of breath, muscular cramps, dizziness, nausea, etc. should be reported immediately. I also understand that I may terminate any exercise session of exercise test at any time for any reason I choose.

I understand that I will be expected to also keep records of my food intake and abstain from all other forms of physical activity while I am participating in the study.

It has been explained to me that there exists the possibility of certain changes occurring during the exercise tests and during the exercise sessions which place my health at risk. These include abnormal blood pressure, rapid or very slow heart rates, irregular heart rhythms, and abnormal blood flow patterns. Left unattended, these changes could lead to unconsciousness, heart attack, and even death. I understand that the chances of these changes occurring are very rare, but that the possibility does exist. Emergency resuscitation equipment and personnel trained in their use are available on site if required to deal with such a situation.

I understand that I am to participate in this study without monetary compensation and that there will be no cost to me for my participation. If I have any questions about the research, my responsibilities, or my rights, I understand that Art W. Siemann at 689-7017 will be happy to answer them.

I understand that anonymity will be accomplished by a number coding system and that only the researchers will have knowledge of my name. I have been informed that the results of this study will be published and that all data will be presented in a manner which prevents their association to me.

The benefits of my participation in this study have been explained to me to include an improvement in cardiorespiratory fitness, weight loss, reduction in body fat, and elevation of resting energy expenditure. I understand that any changes made as a result of my participation may be only temporary changes and that it will be my responsibility to continue a regular program of exercise if these changes are to remain long-term. I also understand that regular analysis of my diet throughout the study may help me control my diet and allow me to eat a more healthy diet.

I understand that my decision whether or not to participate will not cause prejudice toward me. If I decide to participate, I am free to withdraw my consent and to discontinue participation at any time without penalty or loss of benefits to which I am entitled.

My signature below indicates that I have read and understand this consent form and that I am choosing freely to participate in this study.

____________________________ ____________________________

(Name Printed) (Signature)

____________________________ ____________________________

(Date) (Witness)

Appendix B

<u>Pedal Cadence to Kilogram Meters Conversion on the Schwinn Air-Dyne</u>

Pedal RPM	KPM•min-1	Watts	Horsepower
32	150	24.5	0.033
40	300	49.0	0.066
50	600	98.1	0.132
57	900	147.1	0.197
63	1,200	196.1	0.263
67	1,500	245.2	0.329
72	1,800	294.2	0.395
76	2,100	343.2	0.460
80	2,400	392.3	0.526
82	2,700	441.3	0.592
85	3,000	490.3	0.658

Measuring Work With the Air-Dyne: as an ergometer, the Schwinn Air-Dyne provides workload level readings. These readings are based on the relationship between pedal RPM and the air resistance encountered by the fan wheel. They can be understood in a number of ways: in kilopond meters per minute (KPM•min-1), the measure of work required to move one kilogram one meter in one minute; Watts, a measure of force equal to 6.12 KPM•min-1; and horsepower, a measure of work required to move 550 pounds one foot in one second. (Schwinn, 1988. Schwinn Air-Dyne. Owner's manual. Chicago: <u>Schwinn Bicycle Company</u>, pp. 10-11.)

Appendix C Sample Printout from the Gould 9000 Cardiopulmonary Exercise System Metabolic Cart

INDIRECT CALORIMETRY REPORT

PATIENT NAME:
PATIENT ID NUMBER: 00
WT(LB): 180 WT(KG): 081.6
(MMHG): 755
PATIENT AGE: 39 SEX: MALE
PHYSICIAN:

HT(IN): 72 HT(CM): 183
DATE: 05-MAY-93
BAROMETRIC PRESSURE
ROOM: FSU HP LAB
TESTED BY: Y. L. LIU

INSPIRED O2 CONCENTRATION(%): 20.93
INSPIRED CO2 CONCENTRATION(%): 0.04
URINARY NITROGEN (G/DAY): 10.6

PREDICTED WEIGHT (KG): 73.9
PREDICTED BASAL METABOLIC RATE (KCAL/DAY): 1840
PREDICTED RESTING VO2 (ML/MIN): 266
PREDICTED RESTING VENTILATION (L/MIN): 13.48

INDIRECT CALORIMETRY PROFILE

MIN	KCAL	VE	RR	TV	VO2	O2/KG	VCO2	R	NPR	FetCO2	VD/VT	%O2	%CO2
01	424	8.4	8	1.05	69	.85	37	.54	2.15			20.03	.58
02	1859	8.2	6	1.44	256	3.14	252	.98	1.04			17.12	3.80
03	2515	7.3	5	1.37	321	3.93	393	1.22	1.32			15.33	6.59
04	2934	7.5	5	1.50	356	4.36	496	1.39	1.52			14.71	8.04
05	3154	7.8	5	1.62	380	4.66	539	1.42	1.54			14.47	8.46
06	2934	7.0	5	1.35	353	4.33	502	1.42	1.55			14.31	8.69
07	3413	8.2	6	1.37	408	5.00	590	1.45	1.56			14.27	8.85
08	3062	7.5	7	1.09	364	4.46	533	1.46	1.60			14.38	8.78
09	3302	7.7	4	1.86	397	4.87	566	1.43	1.54			14.07	9.02
10	3094	7.8	6	1.30	361	4.42	552	1.53	1.68			14.67	8.66
11	3132	7.7	5	1.54	374	4.58	542	1.45	1.58			14.44	8.64
12	3287	8.2	5	1.64	390	4.78	574	1.47	1.60			14.54	8.60
X	2794	7.8	5	1.40	340	4.17	470	1.38	1.51			15.19	7.39

GRAMS CHO (OXIDIZED): 482.55 KCAL CHO (OXIDIZED): 2017.06
GRAMS FAT (SYNTHESIZED): 336.72 KCAL FAT (SYNTHESIZED): 493.97
GRAMS PROTEINS: 66.25 KCAL PROTEINS: 286.20
GRAMS CHO (CONVERTED): 857.63 TOTAL KCAL: 2797.23

% CARBOHYDRATE: 72.1 % FAT: 17.7 % PROTEIN: 10.2

COMMENTS:
SUPINE REST ONE HOUR POST FIVE MILE RUN

INTERPRETATION:

IPM-E0101-04

Appendix D : Pre-Treatment Caloric Intake, Predicted BEE, and Measured REE

ID	Caloric Intake (kcal/day)	Predicted BEE (kcal/day)	Predicted BEE (kcal/hr)	Measured REE (kcal/day)	Measured REE (kcal/hr)
1	1018	1717.98	71.58	930.00	38.75
2	993	1720.01	71.67	882.00	36.75
3	1205	1669.29	69.55	1019.04	42.46
4	1174	1660.28	69.18	966.96	40.29
5	864	1651.68	68.82	789.12	32.88
6	1100	1721.10	71.71	954.00	39.75
7	1072	1699.90	70.83	983.04	40.96
8	1081	1560.22	65.01	901.92	37.58
9	1036	1515.36	63.14	951.12	39.63
10	1105	1637.88	68.25	1002.00	41.75
11	1071	1702.25	70.93	910.08	37.92
12	1044	1584.86	66.04	1031.04	42.96
$\bar{x}$	1063.58	1653.40	68.89	943.36	39.31
SD	87.230	67.903	2.829	67.229	2.801
13	1129	1676.36	69.85	999.12	41.63
14	1024	1674.11	69.75	939.12	39.13
15	1137	1549.31	64.55	1025.04	42.71
16	1016	1620.23	67.51	976.08	40.67
17	982	1629.79	67.91	881.04	36.71
18	927	1556.44	64.85	870.96	36.29
19	1050	1735.13	72.30	966.96	40.29
20	1014	1544.36	64.35	923.04	38.46
21	1088	1639.72	68.32	1093.92	45.58
22	861	1609.23	67.05	820.08	34.17
23	1039	1771.78	73.82	958.08	39.92
24	1056	1742.95	72.62	952.08	39.67
$\bar{x}$	1026.92	1645.78	68.57	950.46	39.60
SD	78.404	76.808	3.200	72.938	3.039
Total Population Sampled					
$\bar{x}$	1045.25	1649.59	68.73	946.91	39.45
SD	83.245	71.005	2.959	68.695	2.862

Appendix E <u>Pre-Treatment BEE Predicted From Body Surface Area</u>

ID	Age (yrs)	Height (inches)	Height (cms)	Weight (lbs)	Weight (kgs)	B.S.A. (m^2)	Predicted BEE (kcal/day)
1	19	65.50	166.37	207.50	94.32	2.02	1717.98
2	22	62.00	157.48	231.00	105.00	2.04	1720.01
3	20	63.50	161.29	204.00	92.73	1.97	1669.29
4	20	64.75	164.46	194.00	88.18	1.96	1660.28
5	21	65.50	166.37	188.50	85.68	1.96	1651.68
6	22	69.00	175.26	192.25	87.39	2.04	1721.10
7	21	66.25	168.27	200.50	91.14	2.01	1699.90
8	21	61.75	156.85	178.75	81.25	1.85	1560.22
9	21	62.50	158.75	159.50	72.50	1.79	1515.36
10	20	64.75	164.46	186.50	84.77	1.93	1637.88
11	19	65.50	166.37	202.25	91.93	2.00	1702.25
12	20	64.75	164.46	168.75	76.70	1.87	1584.86
$\overline{x}$	20.50	64.65	164.20	192.79	87.63	1.95	1653.40
SD	1.000	2.024	5.141	18.815	8.552	0.079	67.903
13	20	66.25	168.27	191.00	86.82	1.98	1676.36
14	25	67.00	170.18	189.25	86.02	1.99	1674.11
15	22	62.75	159.38	169.50	77.05	1.83	1549.31
16	21	66.25	168.27	173.75	78.98	1.92	1620.23
17	20	65.25	165.74	181.00	82.27	1.92	1629.79
18	20	61.75	156.85	176.00	80.00	1.84	1556.44
19	20	68.25	173.35	199.50	90.68	2.05	1735.13
20	21	63.75	161.93	162.25	73.75	1.83	1544.36
21	21	66.75	169.54	177.50	80.68	1.94	1639.72
22	21	65.50	166.37	174.25	79.20	1.90	1609.23
23	21	67.75	172.08	216.25	98.30	2.10	1771.78
24	20	66.75	169.54	210.50	95.68	2.06	1742.95
$\overline{x}$	21.00	65.67	166.79	185.06	84.12	1.95	1645.78
SD	1.414	1.990	5.053	16.636	7.562	0.090	76.808

Both Groups Combined

$\overline{x}$	20.75	65.16	165.50	188.93	85.88	1.95	1649.59
SD	1.225	2.031	5.158	17.811	8.096	0.083	71.006

Appendix F

Pre-Treatment Caloric Deficit

ID	Caloric Intake (kcal/day)	Predicted BEE (kcal/hr)	Sleep (hrs/week)	Measured REE (kcal/hr)	Treatment Expenditure (kcal/week)	Caloric Expenditure (kcal/day)	Caloric Deficit (kcal/day)
1	1018	71.58	48.50	38.75	510	1332.12	314.12
2	993	71.67	46.00	36.75	510	1283.63	290.63
3	1205	69.55	44.50	42.46	510	1384.61	179.61
4	1174	69.18	49.25	40.29	510	1360.48	186.48
5	864	68.82	59.25	32.88	510	1252.58	388.58
6	1100	71.71	50.75	39.75	510	1368.57	268.57
7	1072	70.83	49.25	40.96	510	1373.25	301.25
8	1081	65.01	54.50	37.58	510	1296.44	215.44
9	1036	63.14	44.00	39.63	510	1275.35	239.35
10	1105	68.25	44.75	41.75	510	1354.77	249.77
11	1071	70.93	47.50	37.92	510	1314.03	243.03
12	1044	66.04	43.50	42.96	510	1351.72	307.72
$\overline{x}$	1063.58	68.89	48.48	39.31	510.00	1328.96	265.38
SD	87.230	2.829	4.674	2.801	0.000	43.545	59.374
13	1129	69.85	45.25	41.63	510	1367.30	238.30
14	1024	69.75	40.50	39.13	510	1291.54	267.54
15	1137	64.55	52.50	42.71	510	1375.40	238.40
16	1016	67.51	44.50	40.67	510	1321.16	305.16
17	982	67.91	60.25	36.71	510	1320.64	338.64
18	927	64.85	57.50	36.29	510	1271.12	344.12
19	1050	72.30	47.00	40.29	510	1359.74	309.74
20	1014	64.35	49.00	38.46	510	1278.53	264.53
21	1088	68.32	43.50	45.58	510	1416.89	328.89
22	861	67.05	58.25	34.17	510	1252.65	391.65
23	1039	73.82	52.50	39.92	510	1389.09	350.09
24	1056	72.62	49.00	39.67	510	1361.19	305.19
$\overline{x}$	1026.92	68.57	49.98	39.60	510.00	1333.77	306.85
SD	78.404	3.200	6.311	3.039	0.000	52.158	47.368

Both Groups Combined

$\overline{x}$	1045.25	68.73	49.23	39.45	510.00	1331.37	286.12
SD	83.245	2.958	5.485	2.862	0.000	47.053	56.637

Appendix G **<u>Pre-Treatment Graded Exercise Test</u>**

ID	Weight (lbs)	Weight (kgs)	Speed (rpm)	Load (kps)	Workload (kgm•min-1)	Absolute $\dot{V}O_2$peak (ml•min-1)	Relative $\dot{V}O_2$peak (ml•kg-1•min-1)	Achieved HRmax (bpm)
1	207.50	94.32	55	3.25	1072.5	2627.86	27.86	178
2	231.00	105.00	50	3.00	900	2337.50	22.26	190
3	204.00	92.73	50	3.00	900	2294.55	24.75	187
4	194.00	88.18	55	3.00	990	2449.64	27.78	199
5	188.50	85.68	50	3.00	900	2269.89	26.49	166
6	192.25	87.39	50	3.50	1050	2560.85	29.30	181
7	200.50	91.14	50	4.00	1200	2858.98	31.37	189
8	178.75	81.25	50	3.00	900	2254.38	27.75	193
9	159.50	72.50	50	2.75	825	2081.25	28.71	195
10	186.50	84.77	50	2.00	600	1696.70	20.01	178
11	202.25	91.93	50	2.75	825	2149.26	23.38	200
12	168.75	76.70	50	3.00	900	2238.47	29.18	190
$\bar{x}$	192.79	87.63	50.83	3.02	921.88	2318.28	26.57	187.17
SD	18.81	8.55	1.95	0.47	149.50	293.74	3.32	9.88
13	191.00	86.82	50	3.50	1050	2558.86	29.47	197
14	189.25	86.02	55	3.00	990	2442.08	28.39	189
15	169.50	77.05	50	2.50	750	1954.66	25.37	190
16	173.75	78.98	50	2.50	750	1961.42	24.84	192
17	181.00	82.27	50	3.00	900	2257.95	27.44	195
18	176.00	80.00	50	3.00	900	2250.00	28.12	184
19	199.50	90.68	50	3.00	900	2287.39	25.22	179
20	162.25	73.75	50	2.50	750	1943.13	26.35	186
21	177.50	80.68	50	2.00	600	1682.39	20.85	191
22	174.25	79.20	50	2.25	675	1819.72	22.97	188
23	216.25	98.30	50	3.00	900	2314.03	23.54	201
24	210.50	95.68	50	3.25	975	2447.39	25.58	194
$\bar{x}$	185.06	84.12	50.42	2.79	845.00	2159.92	25.68	190.50
SD	16.636	7.562	1.443	0.437	137.527	278.215	2.477	5.962
Both Groups Combined								
$\bar{x}$	188.93	85.88	50.62	2.91	883.44	2239.10	26.13	188.83
SD	17.811	8.096	1.689	0.459	145.867	291.252	2.902	8.160

Appendix H

Pre-Treatment Percent Body Fat Scores

ID	Wt (lbs)	Wt (kgs)	U W Wt (kgs)	Tare Wt (kgs)	Water Density	Body Density	Body Fat (%)	FFW (kgs)
1	207.50	94.32	8.25	7.95	0.995372	1.01727	36.60	59.80
2	231.00	105.00	9.10	7.95	0.995372	1.02394	33.42	69.90
3	204.00	92.73	7.55	7.95	0.995372	1.00978	40.21	55.45
4	194.00	88.18	7.75	7.95	0.995372	1.01262	38.83	53.94
5	188.50	85.68	8.50	7.95	0.995372	1.02210	34.30	56.30
6	192.25	87.39	8.15	7.85	0.995057	1.01867	35.93	55.99
7	200.50	91.14	8.50	7.85	0.995057	1.02190	34.39	59.79
8	178.75	81.25	7.55	7.85	0.995057	1.01244	38.92	49.63
9	159.50	72.50	8.30	7.85	0.995057	1.02477	33.04	48.55
10	186.50	84.77	6.75	7.85	0.995057	1.00230	43.86	47.59
11	202.25	91.93	8.00	7.95	0.995678	1.01491	37.73	57.25
12	168.75	76.70	7.40	7.95	0.995678	1.00984	40.18	45.89
$\overline{x}$	192.79	87.63	7.98	7.91		1.02	37.28	55.01
SD	18.815	8.552	0.623	0.051		0.007	3.275	6.644
13	191.00	86.82	8.95	7.95	0.995678	1.02727	31.86	59.16
14	189.25	86.02	8.80	7.95	0.995678	1.02568	32.61	57.97
15	169.50	77.05	8.20	7.95	0.995678	1.02055	35.03	50.05
16	173.75	78.98	8.60	8.00	0.994734	1.02469	33.07	52.86
17	181.00	82.27	7.75	8.00	0.994734	1.01291	38.69	50.44
18	176.00	80.00	8.90	8.00	0.994734	1.02834	31.36	54.91
19	199.50	90.68	9.25	8.00	0.994734	1.02901	31.04	62.53
20	162.25	73.75	7.65	8.00	0.994734	1.01302	38.64	45.26
21	177.50	80.68	8.25	7.85	0.995372	1.02155	34.56	52.80
22	174.25	79.20	7.95	7.85	0.995372	1.01800	36.25	50.49
23	216.25	98.30	8.80	7.85	0.995372	1.02347	33.65	65.22
24	210.50	95.68	9.05	7.85	0.995372	1.02689	32.04	65.03
$\overline{x}$	185.06	84.12	8.51	7.94		1.02	34.07	55.56
SD	16.636	7.562	0.536	0.068		0.006	2.645	6.425

Both Groups Combined

$\overline{x}$	188.93	85.88	8.25	7.92		1.02	35.67	55.28
SD	17.811	8.096	0.629	0.061		0.007	3.343	6.398

Appendix I Week Four BEE Predicted From Body Surface Area

ID	Age (yrs)	Height (inches)	Height (cms)	Weight (lbs)	Weight (kgs)	B.S.A. (m^2)	Predicted BEE (kcal/day)
1	19	65.50	166.37	199.75	90.80	1.99	1694.76
2	22	62.00	157.48	228.50	103.86	2.03	1712.57
3	20	63.50	161.29	200.25	91.02	1.96	1658.08
4	20	64.75	164.46	188.75	85.80	1.94	1644.60
5	21	65.50	166.37	183.50	83.41	1.94	1636.78
6	22	69.00	175.26	189.00	85.91	2.03	1711.42
7	21	66.25	168.27	197.75	89.89	2.00	1691.71
8	21	61.75	156.85	176.50	80.23	1.84	1553.52
9	21	62.50	158.75	158.00	71.82	1.79	1510.90
10	20	64.75	164.46	177.75	80.80	1.90	1611.74
11	19	65.50	166.37	200.50	91.14	2.00	1697.01
12	20	64.75	164.46	166.50	75.68	1.86	1578.14
$\bar{x}$	20.50	64.65	164.20	188.90	85.86	1.94	1641.77
SD	1.000	2.024	5.141	18.565	8.439	0.077	66.321
13	20	66.25	168.27	188.75	85.80	1.97	1669.64
14	25	67.00	170.18	187.50	85.23	1.98	1668.91
15	22	62.75	159.38	168.00	76.36	1.83	1544.84
16	21	66.25	168.27	171.25	77.84	1.91	1612.78
17	20	65.25	165.74	179.50	81.59	1.92	1625.31
18	20	61.75	156.85	175.50	79.77	1.84	1554.94
19	20	68.25	173.35	198.25	90.11	2.04	1731.40
20	21	63.75	161.93	163.00	74.09	1.83	1546.60
21	21	66.75	169.54	175.25	79.66	1.93	1633.02
22	21	65.50	166.37	171.75	78.07	1.90	1601.79
23	21	67.75	172.08	213.50	97.05	2.09	1763.59
24	20	66.75	169.54	207.75	94.43	2.05	1734.74
$\bar{x}$	21.00	65.67	166.79	183.33	83.33	1.94	1640.63
SD	1.414	1.990	5.053	16.084	7.311	0.088	74.950
Both Groups Combined							
$\bar{x}$	20.75	65.16	165.50	186.11	84.60	1.94	1641.20
SD	1.225	2.031	5.158	17.223	7.829	0.081	69.214

Appendix J Week Four Caloric Intake, Predicted BEE, and Measured REE

ID	Caloric Intake (kcal/day)	Predicted BEE (kcal/day)	Predicted BEE (kcal/hr)	Measured REE (kcal/day)	Measured REE (kcal/hr)
1	1125	1694.76	70.61	1002.45	41.77
2	1051	1712.57	71.36	973.02	40.54
3	1194	1658.08	69.09	1095.50	45.65
4	1132	1644.60	68.53	1062.28	44.26
5	1012	1636.78	68.20	1007.55	41.98
6	1238	1711.42	71.31	1126.30	46.93
7	1224	1691.71	70.49	1019.18	42.47
8	1263	1553.52	64.73	1032.70	43.03
9	1148	1510.90	62.95	1123.85	46.83
10	1276	1611.74	67.16	1225.62	51.07
11	1295	1697.01	70.71	1067.45	44.48
12	1270	1578.14	65.76	1152.28	48.01
$\overline{x}$	1185.67	1641.77	68.41	1074.02	44.75
SD	92.323	66.320	2.763	73.498	3.062
13	1283	1669.64	69.57	1014.67	42.28
14	1309	1668.91	69.54	922.84	38.45
15	1271	1544.84	64.37	1132.25	47.18
16	1255	1612.78	67.20	998.52	41.60
17	1251	1625.31	67.72	950.89	39.62
18	1186	1554.94	64.79	893.04	37.21
19	1317	1731.40	72.14	957.33	39.89
20	1059	1546.60	64.44	1019.45	42.48
21	1289	1633.02	68.04	1110.15	46.26
22	1054	1601.79	66.74	874.36	36.43
23	1294	1763.59	73.48	979.04	40.79
24	1008	1734.74	72.28	1016.75	42.36
$\overline{x}$	1214.67	1640.63	68.36	989.11	41.21
SD	111.011	74.950	3.123	78.002	3.250
Both Groups Combined					
$\overline{x}$	1200.17	1641.20	68.38	1031.56	42.98
SD	100.944	69.214	2.884	85.873	3.578

Appendix K Week Four Daily Caloric Deficit

ID	Caloric Intake (kcal/day)	Predicted BEE (kcal/hr)	Reported Sleep (hrs/week)	REE (kcal/hr)	Treatment Exp. (kcal/week)	Caloric Exp. (kcal/day)	Caloric Deficit (kcal/day)
1	1125	70.61	51.50	41.77	690	1425.73	300.73
2	1051	71.36	48.00	40.54	690	1387.97	336.97
3	1194	69.09	50.50	45.65	690	1482.67	288.67
4	1132	68.53	51.50	44.26	690	1452.57	320.57
5	1012	68.20	58.50	41.98	690	1426.42	414.42
6	1238	71.31	48.75	46.93	690	1518.48	280.48
7	1224	70.49	52.25	42.47	690	1449.40	225.40
8	1263	64.73	56.75	43.03	690	1433.52	170.52
9	1148	62.95	50.25	46.83	690	1453.01	305.01
10	1276	67.16	50.50	51.07	690	1567.93	291.93
11	1295	70.71	54.25	44.48	690	1498.87	203.87
12	1270	65.76	50.50	48.01	690	1505.86	235.86
$\bar{x}$	1185.67	68.41	51.94	44.75	690.00	1466.87	281.20
SD	92.323	2.764	3.115	3.063	0.000	49.580	65.314
13	1283	69.57	48.50	42.28	690	1430.67	147.67
14	1309	69.54	51.25	38.45	690	1379.89	70.89
15	1271	64.37	56.50	47.18	690	1496.74	225.74
16	1255	67.20	50.75	41.60	690	1408.07	153.07
17	1251	67.72	58.75	39.62	690	1410.39	159.39
18	1186	64.79	55.25	37.21	690	1327.90	141.90
19	1317	72.14	49.75	39.89	690	1416.84	99.84
20	1059	64.44	59.25	42.48	690	1409.87	350.87
21	1289	68.04	50.25	46.26	690	1494.06	205.06
22	1054	66.74	58.25	36.43	690	1330.51	276.51
23	1294	73.48	54.25	40.79	690	1460.28	166.28
24	1008	72.28	53.75	42.36	690	1445.75	437.75
$\bar{x}$	1214.67	68.36	53.88	41.21	690.00	1417.58	202.91
SD	111.011	3.122	3.771	3.251	0.000	54.062	105.973

Both Groups Combined

$\bar{x}$	1200.17	68.38	52.91	42.98	690.00	1442.23	242.06
SD	100.944	2.884	3.525	3.579	0.000	56.632	94.921

Appendix L Week Four Graded Exercise Test

ID	Weight (lbs)	Weight (kgs)	Speed (rpm)	Load (kps)	Workload (kgm•min-1)	Absolute V̇O2peak (ml•min-1)	Relative V̇O2peak (ml•kg-1•min-1)	Achieved HRmax (bpm)
1	199.75	90.80	55	3.50	1155	2772.28	30.53	189
2	228.50	103.86	50	3.00	900	2333.52	22.47	195
3	200.25	91.02	50	3.25	975	2431.08	26.71	192
4	188.75	85.80	55	3.50	1155	2754.78	32.11	198
5	183.50	83.41	50	3.25	975	2404.43	28.83	175
6	189.00	85.91	50	3.50	1050	2555.68	29.75	184
7	197.75	89.89	50	4.00	1200	2854.60	31.76	191
8	176.50	80.23	50	3.25	975	2393.30	29.83	195
9	158.00	71.82	50	3.00	900	2221.36	30.93	192
10	177.75	80.80	50	2.50	750	1967.78	24.36	189
11	200.50	91.14	50	3.00	900	2288.98	25.12	196
12	166.50	75.68	50	3.50	1050	2519.89	33.30	195
$\overline{x}$	188.90	85.86	50.83	3.27	998.75	2458.14	28.81	190.92
SD	18.565	8.439	1.946	0.376	130.526	253.283	3.401	6.302
13	188.75	85.80	50	3.50	1050	2555.28	29.78	195
14	187.50	85.23	55	3.25	1072.5	2596.05	30.46	192
15	168.00	76.36	50	2.75	825	2094.77	27.43	198
16	171.25	77.84	50	2.75	825	2099.94	26.98	194
17	179.50	81.59	50	3.00	900	2255.57	27.64	199
18	175.50	79.77	50	3.00	900	2249.20	28.20	189
19	198.25	90.11	50	3.00	900	2285.40	25.36	191
20	163.00	74.09	50	2.75	825	2086.82	28.17	190
21	175.25	79.66	50	2.50	750	1963.81	24.65	197
22	171.75	78.07	50	2.50	750	1958.24	25.08	195
23	213.50	97.05	50	3.00	900	2309.66	23.80	199
24	207.75	94.43	50	3.25	975	2443.01	25.87	198
$\overline{x}$	183.33	83.33	50.42	2.94	889.38	2241.48	26.95	194.75
SD	16.084	7.311	1.443	0.304	103.749	212.013	2.055	3.571
Both Groups Combined								
$\overline{x}$	186.11	84.60	50.62	3.10	944.06	2349.81	27.88	192.83
SD	17.223	7.829	1.689	0.375	128.128	253.820	2.907	5.378

Appendix M Week Eight BEE Predicted From Body Surface Area

ID	Age (yrs)	Height (inches)	Height (cms)	Weight (lbs)	Weight (kgs)	B.S.A. (m^2)	Predicted BEE (kcal/day)
1	19	65.50	166.37	182.50	82.95	1.93	1643.09
2	22	62.00	157.48	206.25	93.75	1.95	1646.29
3	20	63.50	161.29	189.00	85.91	1.92	1624.48
4	20	64.75	164.46	180.25	81.93	1.91	1619.21
5	21	65.50	166.37	169.75	77.16	1.89	1595.83
6	22	69.00	175.26	174.25	79.20	1.97	1667.49
7	21	66.25	168.27	177.50	80.68	1.93	1631.40
8	22	61.75	156.85	171.75	78.07	1.82	1539.37
9	21	62.50	158.75	149.75	68.07	1.76	1486.32
10	20	64.75	164.46	172.00	78.18	1.88	1594.56
11	19	65.50	166.37	190.25	86.48	1.96	1666.30
12	20	64.75	164.46	148.75	67.61	1.80	1525.11
$\bar{x}$	20.58	64.65	164.20	176.00	80.00	1.89	1603.29
SD	1.084	2.024	5.141	16.117	7.326	0.067	58.019
13	20	66.25	168.27	186.50	84.77	1.96	1662.91
14	25	67.00	170.18	185.75	84.43	1.97	1663.71
15	22	62.75	159.38	165.25	75.11	1.82	1536.65
16	21	66.25	168.27	169.75	77.16	1.90	1608.31
17	20	65.25	165.74	176.00	80.00	1.91	1614.86
18	20	61.75	156.85	169.75	77.16	1.82	1537.77
19	20	68.25	173.35	195.50	88.86	2.03	1723.18
20	21	63.75	161.93	161.75	73.52	1.83	1542.87
21	21	66.75	169.54	174.00	79.09	1.93	1629.29
22	21	65.50	166.37	169.50	77.05	1.89	1595.08
23	21	67.75	172.08	211.25	96.02	2.08	1756.89
24	20	66.75	169.54	204.50	92.95	2.04	1725.03
$\bar{x}$	21.00	65.67	166.79	180.79	82.18	1.93	1633.05
SD	1.414	1.990	5.053	15.977	7.262	0.089	75.470

Both Groups Combined

$\bar{x}$	20.79	65.16	165.50	178.40	81.09	1.91	1618.17
SD	1.250	2.031	5.158	15.884	7.220	0.079	67.565

Appendix N Week Eight Caloric Intake, Predicted BEE, and Measured REE

ID	Caloric Intake (kcal/day)	Predicted BEE (kcal/day)	Predicted BEE (kcal/hr)	Measured REE (kcal/day)	Measured REE (kcal/hr)
1	1227	1643.09	68.46	1212.78	50.53
2	1220	1646.29	68.60	1198.08	49.92
3	1289	1624.48	67.69	1271.50	52.98
4	1245	1619.21	67.47	1289.18	53.72
5	1149	1595.83	66.49	1156.50	48.19
6	1251	1667.49	69.48	1207.64	50.32
7	1273	1631.40	67.97	1093.28	45.55
8	1280	1539.37	64.14	1175.00	48.96
9	1276	1486.32	61.93	1235.50	51.48
10	1304	1594.56	66.44	1302.56	54.27
11	1365	1666.30	69.43	1167.04	48.63
12	1297	1525.11	63.55	1218.68	50.78
$\bar{x}$	1264.67	1603.29	66.80	1210.64	50.44
SD	53.130	58.020	2.417	59.583	2.483
13	1153	1662.91	69.29	1066.45	44.44
14	1224	1663.71	69.32	1052.80	43.87
15	1229	1536.65	64.03	1129.62	47.07
16	1158	1608.31	67.01	1014.95	42.29
17	1056	1614.86	67.29	1084.26	45.18
18	1205	1537.77	64.07	999.48	41.65
19	1186	1723.18	71.80	1024.32	42.68
20	1228	1542.87	64.29	1063.45	44.31
21	1223	1629.29	67.89	1128.88	47.04
22	965	1595.08	66.46	885.00	36.88
23	1270	1756.89	73.20	1041.52	43.40
24	1002	1725.03	71.88	1008.79	42.03
$\bar{x}$	1158.25	1633.05	68.04	1041.63	43.40
SD	98.198	75.471	3.145	65.219	2.717
Both Groups Combined					
$\bar{x}$	1211.46	1618.17	67.42	1126.14	46.92
SD	94.425	67.565	2.815	105.757	4.407

Appendix O

Week Eight Daily Caloric Deficit

ID	Caloric Intake (kcal/day)	Predicted BEE (kcal/hr)	Reported Sleep (hrs/week)	REE (kcal/hr)	Treatment Exp. (kcal/week)	Caloric Exp. (kcal/day)	Caloric Deficit (kcal/day)
1	1227	68.46	41.75	50.53	900	1570.93	343.93
2	1220	68.60	44.50	49.92	900	1567.40	347.40
3	1289	67.69	41.25	52.98	900	1615.68	326.68
4	1245	67.47	40.50	53.72	900	1621.91	376.91
5	1149	66.49	44.75	48.19	900	1517.02	368.02
6	1251	69.48	46.50	50.32	900	1588.63	337.63
7	1273	67.97	43.50	45.55	900	1488.40	215.40
8	1280	64.14	40.25	48.96	900	1518.90	238.90
9	1276	61.93	45.50	51.48	900	1559.62	283.62
10	1304	66.44	42.75	54.27	900	1635.78	331.78
11	1365	69.43	44.00	48.63	900	1562.93	197.93
12	1297	63.55	43.25	50.78	900	1555.89	258.89
$\bar{x}$	1264.67	66.80	43.21	50.44	900.00	1566.92	302.26
SD	53.130	2.417	1.980	2.483	0.000	44.499	61.097
13	1153	69.29	41.75	44.44	900	1458.64	305.64
14	1224	69.32	44.50	43.87	900	1465.64	241.64
15	1229	64.03	46.25	47.07	900	1493.21	264.21
16	1158	67.01	40.25	42.29	900	1401.47	243.47
17	1056	67.29	44.50	45.18	900	1459.05	403.05
18	1205	64.07	49.50	41.65	900	1407.21	202.21
19	1186	71.80	41.25	42.68	900	1443.09	257.09
20	1228	64.29	43.00	44.31	900	1437.55	209.55
21	1223	67.89	46.50	47.04	900	1518.34	295.34
22	965	66.46	59.25	36.88	900	1360.57	395.57
23	1270	73.20	48.75	43.40	900	1504.71	234.71
24	1002	71.88	55.50	42.03	900	1474.16	472.16
$\bar{x}$	1158.25	68.04	46.75	43.40	900.00	1451.97	293.72
SD	98.198	3.144	5.771	2.717	0.000	45.582	85.653

Both Groups Combined

$\bar{x}$	1211.46	67.42	44.98	46.92	900.00	1509.45	297.99
SD	94.425	2.815	4.591	4.406	0.000	73.403	72.891

Appendix P

Week Eight Graded Exercise Test

ID	Weight (lbs)	Weight (kgs)	Speed (rpm)	Load (kps)	Workload (kgm•min-1)	Absolute $\dot{V}O2peak$ (ml•min-1)	Relative $\dot{V}O2peak$ (ml•kg-1•min-1)	Achieved HRmax (bpm)
1	182.50	82.95	55	3.50	1155	2744.84	33.09	196
2	206.25	93.75	50	3.25	975	2440.62	26.03	199
3	189.00	85.91	55	3.50	1155	2755.18	32.07	199
4	180.25	81.93	55	3.50	1155	2741.26	33.46	197
5	169.75	77.16	50	3.50	1050	2525.06	32.73	191
6	174.25	79.20	50	3.75	1125	2674.72	33.77	195
7	177.50	80.68	55	3.75	1237.5	2893.64	35.86	201
8	171.75	78.07	55	3.25	1072.5	2570.99	32.93	198
9	149.75	68.07	55	3.25	1072.5	2535.99	37.26	195
10	172.00	78.18	55	3.00	990	2414.64	30.88	197
11	190.25	86.48	55	3.25	1072.5	2600.42	30.07	199
12	148.75	67.61	50	3.75	1125	2634.15	38.96	200
$\bar{x}$	176.00	80.00	53.33	3.44	1098.75	2627.62	33.09	197.25
SD	16.117	7.326	2.462	0.241	74.898	141.146	3.372	2.734
13	186.50	84.77	50	3.50	1050	2551.70	30.10	195
14	185.75	84.43	55	3.25	1072.5	2593.26	30.71	193
15	165.25	75.11	50	3.00	900	2232.90	29.73	195
16	169.75	77.16	50	3.00	900	2240.06	29.03	192
17	176.00	80.00	50	3.25	975	2392.50	29.91	198
18	169.75	77.16	50	3.50	1050	2525.06	32.73	193
19	196.50	89.32	50	3.25	975	2425.11	27.15	195
20	161.75	73.52	55	3.00	990	2398.33	32.62	193
21	174.00	79.09	50	3.00	900	2246.82	28.41	190
22	169.50	77.05	50	3.00	900	2239.66	29.07	196
23	211.25	96.02	55	3.25	1072.5	2633.83	27.43	191
24	204.50	92.95	55	3.00	990	2466.34	26.53	194
$\bar{x}$	180.88	82.22	51.67	3.17	981.25	2412.13	29.45	193.75
SD	16.063	7.301	2.462	0.195	69.245	146.686	1.963	2.221

Both Groups Combined

$\bar{x}$	178.44	81.11	52.50	3.30	1040.00	2519.88	31.27	195.50
SD	15.932	7.242	2.554	0.255	92.616	178.698	3.277	3.022

Appendix Q Post-Treatment BEE Predicted From Body Surface Area

ID	Age (yrs)	Height (inches)	Height (cms)	Weight (lbs)	Weight (kgs)	B.S.A. (m^2)	Predicted BEE (kcal/day)
1	19	65.50	166.37	176.75	80.34	1.91	1625.86
2	22	62.00	157.48	194.50	88.41	1.91	1611.29
3	20	63.50	161.29	188.25	85.57	1.91	1622.24
4	20	64.75	164.46	175.50	79.77	1.89	1605.02
5	21	65.50	166.37	162.25	73.75	1.86	1573.49
6	22	69.00	175.26	168.75	76.70	1.95	1651.11
7	21	66.25	168.27	170.25	77.39	1.91	1609.80
8	22	61.75	156.85	163.75	74.43	1.79	1515.54
9	21	62.50	158.75	144.50	65.68	1.74	1470.69
10	20	64.75	164.46	165.50	75.23	1.86	1575.15
11	19	65.50	166.37	181.75	82.61	1.93	1640.84
12	20	64.75	164.46	144.25	65.57	1.78	1511.67
$\bar{x}$	20.58	64.65	164.20	169.67	77.12	1.87	1584.39
SD	1.084	2.024	5.141	15.315	6.962	0.066	57.006
13	20	66.25	168.27	182.75	83.07	1.95	1651.71
14	25	67.00	170.18	181.00	82.27	1.96	1649.60
15	22	62.75	159.38	159.75	72.61	1.80	1520.27
16	21	66.25	168.27	166.25	75.57	1.89	1597.89
17	20	65.25	165.74	172.25	78.30	1.89	1603.66
18	20	61.75	156.85	168.50	76.59	1.81	1534.03
19	20	68.25	173.35	190.25	86.48	2.02	1707.50
20	21	63.75	161.93	155.25	70.57	1.80	1523.51
21	21	66.75	169.54	168.75	76.70	1.91	1613.66
22	21	65.50	166.37	160.25	72.84	1.86	1567.53
23	21	67.75	172.08	200.75	91.25	2.04	1725.62
24	20	66.75	169.54	199.25	90.57	2.02	1709.35
$\bar{x}$	21.00	65.67	166.79	175.42	79.73	1.91	1617.03
SD	1.414	1.990	5.053	15.325	6.966	0.086	73.091

Both Groups Combined

$\bar{x}$	20.79	65.16	165.50	172.54	78.43	1.89	1600.71
SD	1.250	2.031	5.158	15.268	6.940	0.078	66.235

Appendix R Post-Treatment Graded Exercise Test

ID	Weight (lbs)	Weight (kgs)	Speed (rpm)	Load (kps)	Workload (kgm•min-1)	Absolute $\dot{V}O2peak$ (ml•min-1)	Relative $\dot{V}O2peak$ (ml•kg-1•min-1)	Achieved HRmax (bpm)
1	176.75	80.34	55	3.75	1237.5	2892.44	36.00	198
2	194.50	88.41	55	4.00	1320	3077.43	34.81	200
3	188.25	85.57	55	4.00	1320	3067.49	35.85	199
4	175.50	79.77	55	4.00	1320	3047.20	38.20	198
5	162.25	73.75	50	4.00	1200	2798.12	37.94	196
6	168.75	76.70	55	4.25	1402.5	3193.22	41.63	199
7	170.25	77.39	55	4.00	1320	3038.85	39.27	200
8	163.75	74.43	55	3.75	1237.5	2871.76	38.58	199
9	144.50	65.68	55	3.75	1237.5	2841.14	43.26	197
10	165.50	75.23	55	3.50	1155	2717.80	36.13	198
11	181.75	82.61	55	3.75	1237.5	2900.40	35.11	196
12	144.25	65.57	55	4.00	1320	2997.49	45.72	201
$\overline{x}$	169.67	77.12	54.58	3.90	1275.62	2953.61	38.54	198.42
SD	15.315	6.962	1.443	0.198	68.773	137.962	3.431	1.564
13	182.75	83.07	50	3.75	1125	2688.24	32.36	196
14	181.00	82.27	55	4.00	1320	3055.95	37.14	194
15	159.75	72.61	50	3.50	1050	2509.15	34.55	199
16	166.25	75.57	50	3.25	975	2376.99	31.45	190
17	172.25	78.30	55	3.50	1155	2728.53	34.85	197
18	168.50	76.59	50	3.75	1125	2665.57	34.80	196
19	190.25	86.48	55	3.50	1155	2757.17	31.88	196
20	155.25	70.57	55	3.50	1155	2701.49	38.28	194
21	168.75	76.70	50	3.50	1050	2523.47	32.90	194
22	160.25	72.84	55	3.25	1072.5	2552.69	35.04	195
23	200.75	91.25	55	3.50	1155	2773.88	30.40	190
24	199.25	90.57	55	3.50	1155	2771.49	30.60	192
$\overline{x}$	175.42	79.73	52.92	3.54	1124.38	2675.38	33.69	194.42
SD	15.325	6.966	2.575	0.209	84.760	172.951	2.508	2.712

Both Groups Combined

$\overline{x}$	172.54	78.43	53.75	3.72	1200.00	2814.50	36.12	196.42
SD	15.268	6.940	2.212	0.269	108.008	208.813	3.844	2.977

Appendix S

Post-Treatment Percent Body Fat Scores

ID	Wt (lbs)	Wt (kgs)	U W Wt (kgs)	Tare Wt (kgs)	Water Density	Body Density	Body Fat (%)	FFW (kgs)
1	176.75	80.34	9.55	8.05	0.995678	1.03620	27.71	58.08
2	194.50	88.41	9.85	8.05	0.995678	1.03643	27.60	64.01
3	188.25	85.57	9.05	8.05	0.995678	1.02768	31.67	58.47
4	175.50	79.77	8.85	8.05	0.995678	1.02708	31.95	54.29
5	162.25	73.75	8.95	8.05	0.995678	1.03080	30.21	51.47
6	168.75	76.70	9.00	8.05	0.995678	1.03028	30.45	53.35
7	170.25	77.39	8.80	8.05	0.995678	1.02726	31.87	52.73
8	163.75	74.43	8.85	7.95	0.995976	1.03051	30.34	51.85
9	144.50	65.68	9.10	7.95	0.995976	1.03882	26.50	48.28
10	165.50	75.23	8.20	7.95	0.995976	1.02105	34.79	49.05
11	181.75	82.61	9.75	8.10	0.995057	1.03714	27.28	60.08
12	144.25	65.57	8.55	8.10	0.995057	1.02746	31.77	44.74
$\overline{x}$	169.67	77.12	9.04	8.03		1.03	30.18	53.86
SD	15.315	6.962	0.478	0.054		0.005	2.465	5.475
13	182.75	83.07	9.60	8.10	0.995057	1.03498	28.27	59.58
14	181.00	82.27	9.25	8.10	0.995057	1.03077	30.23	57.41
15	159.75	72.61	8.90	8.10	0.995057	1.02984	30.66	50.35
16	166.25	75.57	8.95	7.90	0.995372	1.03216	29.57	53.22
17	172.25	78.30	8.30	7.90	0.995372	1.02222	34.24	51.49
18	168.50	76.59	9.05	7.90	0.995372	1.03312	29.13	54.28
19	190.25	86.48	9.45	7.90	0.995372	1.03417	28.65	61.71
20	155.25	70.57	8.35	7.90	0.995372	1.02546	32.71	47.49
21	168.75	76.70	8.40	7.90	0.995372	1.02406	33.37	51.11
22	160.25	72.84	8.35	8.05	0.995678	1.02248	34.12	47.99
23	200.75	91.25	9.00	8.05	0.995678	1.02533	32.77	61.35
24	199.25	90.57	9.55	7.95	0.995057	1.03317	29.11	64.21
$\overline{x}$	175.42	79.73	8.93	7.98		1.03	31.07	55.01
SD	15.325	6.966	0.484	0.092		0.005	2.229	5.683

Both Groups Combined

$\overline{x}$	172.54	78.43	8.99	8.01		1.03	30.62	54.44
SD	15.268	6.940	0.474	0.078		0.005	2.343	5.489

Appendix T

Pre-Treatment Health and Activity Questionnaire

1. Descriptive Information

Last Name	First Name	Middle Initial

Date of Birth	Gender	Home Phone

Address	City, State	Zip

Name and Phone of a Close Friend In Case of an Emergency

2. Section A

- When was the last time you had a physical examination?

- If you are allergic to any medications, foods, or other substances, please list them.

- If you have been told that you have any chronic or serious illness, please list them.

- Give the following information pertaining to the last three times you have been hospitalized. (Women: do not list normal pregnancies.)

	Hospitalization #1	Hospitalization #2	Hospitalization #3
Type of operation			
Date of hospitalization			

3. Section B

During the past twelve months:

- Has a physical prescribed any form of medication for you? **Yes** ___ **No** ___
- Has your weight fluctuated more than a few pounds? **Yes** ___ **No** ___

- Did you attempt to bring about this weight change through diet and/or exercise? **Yes** __ **No** __
- Have you experienced any faintness, lightheadedness, or blackouts? **Yes** __ **No** __
- Have you occasionally had trouble sleeping? **Yes** __ **No** __
- Have you experienced any blurred vision? **Yes** __ **No** __
- Have you had any severe headaches? **Yes** __ **No** __
- Have you experienced chronic morning cough? **Yes** __ **No** __
- Have you experienced any temporary change in your speech pattern such as slurring or loss of speech? **Yes** __ **No** __
- Have you felt unusually nervous or anxious for no apparent reason? **Yes** __ **No** __
- Have you experienced unusual heartbeats such as skipped beats or palpitations? **Yes** __ **No** __
- Have you experienced periods in which you heart felt as though it were racing for no apparent reason? **Yes** __ **No** __
- Have you experienced low back pain? **Yes** __ **No** __
- Have you experienced pain in your hips, knees, ankles, or feet? **Yes** __ **No** __

If you answered yes to any of the above, please elaborate.

____

____

____

At present:

- Do you experience shortness of breath or loss of breath while walking with others you own age? **Yes** __ **No** __
- Do you experience sudden tingling, numbness, or loss of feeling in your arms, hands, legs, feet, or face? **Yes** __ **No** __
- Have you ever noticed that you hands or feet sometimes feel cooler than other parts of your body? **Yes** __ **No** __
- Do you experience swelling of your feet or ankles? **Yes** __ **No** __
- Do you get pains or cramps in your legs? **Yes** __ **No** __

- Do you experience any pain or discomfort in your chest? **Yes** ___ **No** ___
- Do you experience any pressure or heaviness in your chest? **Yes** ___ **No** ___
- Have you ever been told that your blood pressure was abnormal? **Yes** ___ **No** ___
- Have you ever been told that your cholesterol or triglyceride level was high? **Yes** ___ **No** ___
- Do you have diabetes? **Yes** ___ **No** ___

  If yes, how is it controlled?

  ___ dietary means ___ insulin injection
  ___ oral medication ___ uncontrolled

- How often would you characterize your stress level as being high?

  ___ occasionally ___ frequently ___ constantly

- Have you ever been told that you have any of the following illness?

  ___ myocardial infarction ___ heart attack
  ___ coronary thrombosis ___ heart disease
  ___ coronary occlusion ___ heart murmur
  ___ arteriosclerosis ___ heart block
  ___ rheumatic fever ___ aneurysm
  ___ heart failure ___ angina

4. Section C

Has any member of your immediate family been treated for or suspected to have had any of these conditions? If yes, then please identify their relationship to you (father, mother, sister, brother, etc.).

- Diabetes
- Heart Disease
- Stroke
- High Blood Pressure
- High Cholesterol or Triglycerides

5. Lifestyle Evaluation

Smoking Habits:

- Have you ever smoked cigarettes, cigars, or a pipe? **Yes** ___ **No** ___

- Do you smoke presently? **Yes** ___ **No** ___

  Cigarettes per day? _____
  Cigars per day? _____
  Pipefuls per day? _____

- At what age did you start smoking? _____ years

- If you have quit smoking, when did you quit? ________________

Drinking Habits:

- During the past month, how many days did you drink alcoholic beverages? _____ days

- During the past month, how many times did you have five or more drinks per occasion? _____ times

- On the average, how many glasses of beer, wine, or mixed drinks do you consume per week?

  _____ glasses or cans of beer

  _____ glasses of wine

  _____ glasses of mixed drinks

Exercise Habits:

- Do you exercise vigorously on a regular basis? **Yes** ___ **No** ___
- What activities do you engage in on a regular basis? (Include strenuous work activities)

- If you walk, run, or jog, what is the average number of miles you cover per workout? _____ miles
- How many minutes on the average is each of your exercise workouts? _____ minutes
- How many workouts per week do you participate in on the average? _____ workouts
- Is your occupation:

  _____ inactive (i.e., desk job)

  _____ light work (i.e., housework, light carpentry)

  _____ heavy work (i.e., manual labor, lifting)

- Check those activities that you would prefer in a regular exercise program for yourself:

_____	walking/running/jogging	_____	handball/racquetball
_____	stationary running	_____	basketball
_____	jumping rope	_____	swimming
_____	bicycling	_____	tennis
_____	stationary cycling	_____	aerobic dance
_____	weight training	_____	skating
_____	other (specify: ________________________		

Appendix U

Post-Treatment Assessment of the Exercise Sessions Questionnaire

Check which group you participated in: **Group A** 12 **Group B** 12

As a result of participation in this study:

1. How satisfied are you with the changes you have experienced?

very dissatisfied	dissatisfied	neither satisfied or dissatisfied	satisfied	very satisfied	other: specify
			A 3 B 4	A 9 B 8	

2.How would you rate the exercise sessions when the study began?

impossible to finish	boring	necessary to see results	fun	exciting	other: specify
A 5 B 1	A 1 B 2	A 3 B 4	A 3 B 5		

3.How would you rate the exercise sessions at the conclusion of the study?

impossible to finish	boring	necessary to see results	fun	exciting	other: specify
A 1 B 1	A 1 B 6	A 2 B 4	A 5 B 1	A 3 B 0	

4. To what do you attribute the change in attitude about the exercise sessions if there was a difference in how you responded to #2 and #3 above?

____

5. Do you plan to continue exercising in the same manner as you performed during the 12-week study? ___ Yes ___ No A: 4Y 8N; B: 5Y 7N

6. Do you plan to try something else as your major form of physical activity while you remain at college? ___ Yes ___ No A: 12Y 0N; B: 10Y 2N

   If yes, what will it be? ____

Thank you very much for your long hours of work and your patience during the testing periods. You are always welcome to call me (689-7017) if you have any questions about your results or simply if you wish to talk about your health and fitness future. Best wishes, stay healthy and happy.

-- Art

Appendix V Statistical Analyses

Section 1: Summary Statistics

Descriptive Statistics
Split By: Group

	Mean	Std. Dev.	Std. Error	Count	Minimum	Maximum	# Missing
PRE FFW, Total	55.282	6.399	1.306	24	45.253	69.909	0
PRE FFW, A	55.005	6.646	1.918	12	45.885	69.909	0
PRE FFW, B	55.560	6.425	1.855	12	45.253	65.219	0
POST FFW, Total	54.439	5.488	1.120	24	44.737	64.204	0
POST FFW, A	53.865	5.474	1.580	12	44.737	64.008	0
POST FFW, B	55.013	5.682	1.640	12	47.485	64.204	0
Pre-Wt, Total	85.876	8.097	1.653	24	72.500	105.000	0
Pre-Wt, A	87.632	8.553	2.469	12	72.500	105.000	0
Pre-Wt, B	84.119	7.562	2.183	12	73.750	98.300	0
Wt-4, Total	84.598	7.829	1.598	24	71.820	103.860	0
Wt-4, A	85.863	8.438	2.436	12	71.820	103.860	0
Wt-4, B	83.333	7.312	2.111	12	74.090	97.050	0
Wt-8, Total	81.107	7.242	1.478	24	67.610	96.020	0
Wt-8, A	79.999	7.326	2.115	12	67.610	93.750	0
Wt-8, B	82.215	7.301	2.107	12	73.520	96.020	0
Post-Wt, Total	78.428	6.941	1.417	24	65.570	91.250	0
Post-Wt, A	77.121	6.962	2.010	12	65.570	88.410	0
Post-Wt, B	79.735	6.966	2.011	12	70.570	91.250	0
Pre-Fat, Total	35.675	3.343	.682	24	31.040	43.860	0
Pre-Fat, A	37.284	3.275	.945	12	33.040	43.860	0
Pre-Fat, B	34.067	2.645	.764	12	31.040	38.690	0
Post-Fat, Total	30.624	2.342	.478	24	26.500	34.790	0
Post-Fat, A	30.178	2.464	.711	12	26.500	34.790	0
Post-Fat, B	31.069	2.229	.643	12	28.270	34.240	0

Descriptive Statistics
Split By: Group

	Mean	Std. Dev.	Std. Error	Count	Minimum	Maximum	# Missing
Pre-L/min, Total	2.239	.291	.059	24	1.682	2.859	0
Pre-L/min, A	2.318	.294	.085	12	1.697	2.859	0
Pre-L/min, B	2.160	.278	.080	12	1.682	2.559	0
4 L/min, Total	2.350	.254	.052	24	1.958	2.855	0
4 L/min, A	2.458	.253	.073	12	1.968	2.855	0
4 L/min, B	2.241	.212	.061	12	1.958	2.596	0
8 L/min, Total	2.520	.179	.036	24	2.233	2.894	0
8 L/min, A	2.628	.141	.041	12	2.415	2.894	0
8 L/min, B	2.412	.147	.042	12	2.233	2.634	0
Post-L/min, Total	2.814	.209	.043	24	2.377	3.193	0
Post-L/min, A	2.954	.138	.040	12	2.718	3.193	0
Post-L/min, B	2.675	.173	.050	12	2.377	3.056	0
Pre-VO2, Total	26.124	2.903	.592	24	20.010	31.370	0
Pre-VO2, A	26.570	3.324	.959	12	20.010	31.370	0
Pre-VO2, B	25.678	2.477	.715	12	20.850	29.470	0
4 VO2, Total	27.880	2.907	.593	24	22.470	33.300	0
4 VO2, A	28.808	3.400	.981	12	22.470	33.300	0
4 VO2, B	26.952	2.056	.593	12	23.800	30.460	0
8 VO2, Total	31.272	3.278	.669	24	26.030	38.960	0
8 VO2, A	33.093	3.373	.974	12	26.030	38.960	0
8 VO2, B	29.452	1.963	.567	12	26.530	32.730	0
Post-VO2, Total	36.115	3.845	.785	24	30.400	45.720	0
Post-VO2, A	38.542	3.432	.991	12	34.810	45.720	0
Post-VO2, B	33.688	2.508	.724	12	30.400	38.280	0
Pre-REE, Total	946.910	68.695	14.022	24	789.120	1093.920	0
Pre-REE, A	943.360	67.229	19.407	12	789.120	1031.040	0
Pre-REE, B	950.460	72.938	21.055	12	820.080	1093.920	0
4 REE, Total	1031.561	85.873	17.529	24	874.360	1225.620	0
4 REE, A	1074.015	73.498	21.217	12	973.020	1225.620	0
4 REE, B	989.108	78.002	22.517	12	874.360	1132.250	0
8 REE, Total	1126.136	105.757	21.588	24	885.000	1302.560	0
8 REE, A	1210.645	59.583	17.200	12	1093.280	1302.560	0
8 REE, B	1041.627	65.219	18.827	12	885.000	1129.620	0
Post-REE, Total	1311.222	159.307	32.519	24	1008.160	1590.410	0
Post-REE, A	1447.323	88.049	25.417	12	1244.630	1590.410	0
Post-REE, B	1175.122	69.983	20.202	12	1008.160	1274.880	0

Section 2: Comparison of Pre-Treatment Mean Scores by Group

Unpaired t-test for Pre-Wt
Grouping Variable: Group
Hypothesized Difference = 0

	Mean Diff.	DF	t-Value	P-Value
A, B	3.513	22	1.066	.2980

Group Info for Pre-Wt
Grouping Variable: Group

	Count	Mean	Variance	Std. Dev.	Std. Err
A	12	87.632	73.156	8.553	2.469
B	12	84.119	57.183	7.562	2.183

Unpaired t-test for Pre-Fat
Grouping Variable: Group
Hypothesized Difference = 0

	Mean Diff.	DF	t-Value	P-Value
A, B	3.218	22	2.647	.0147

Group Info for Pre-Fat
Grouping Variable: Group

	Count	Mean	Variance	Std. Dev.	Std. Err
A	12	37.284	10.725	3.275	.945
B	12	34.067	6.998	2.645	.764

Unpaired t-test for PRE FFW
Grouping Variable: Group
Hypothesized Difference = 0

	Mean Diff.	DF	t-Value	P-Value
A, B	-.555	22	-.208	.8372

Group Info for PRE FFW
Grouping Variable: Group

	Count	Mean	Variance	Std. Dev.	Std. Err
A	12	55.005	44.164	6.646	1.918
B	12	55.560	41.275	6.425	1.855

Unpaired t-test for Pre-L/min
Grouping Variable: Group
Hypothesized Difference = 0

	Mean Diff.	DF	t-Value	P-Value
A, B	.158	22	1.356	.1889

Group Info for Pre-L/min
Grouping Variable: Group

	Count	Mean	Variance	Std. Dev.	Std. Err
A	12	2.318	.086	.294	.085
B	12	2.160	.077	.278	.080

Unpaired t-test for Pre-VO2
Grouping Variable: Group
Hypothesized Difference = 0

	Mean Diff.	DF	t-Value	P-Value
A, B	.892	22	.745	.4640

Group Info for Pre-VO2
Grouping Variable: Group

	Count	Mean	Variance	Std. Dev.	Std. Err
A	12	26.570	11.046	3.324	.959
B	12	25.678	6.135	2.477	.715

Unpaired t-test for Pre-REE
Grouping Variable: Group
Hypothesized Difference = 0

	Mean Diff.	DF	t-Value	P-Value
A, B	-7.100	22	-.248	.8065

Group Info for Pre-REE
Grouping Variable: Group

	Count	Mean	Variance	Std. Dev.	Std. Err
A	12	943.360	4519.739	67.229	19.407
B	12	950.460	5319.895	72.938	21.055

Section 3: Repeated Measures Design ANOVA

Effect	df Effect	MS Effect	df Error	MS Error	F	P-Level
Total Body Weight						
Group	1	2.2083	22	224.3951	.0098	.921876
Time	3	274.5705	66	1.6967	161.8262	.000000
G x T	3	60.2403	66	1.6967	35.5044	.000000
Percent Body Fat						
Group	1	16.2401	22	12.5186	1.2973	.266962
Time	1	306.2320	22	1.8635	164.3346	.000000
G x T	1	50.6352	22	1.8635	27.1726	.000032
Fat-Free Weight						
Group	1	8.7066	22	70.2711	.1239	.728192
Time	1	8.5371	22	3.5749	2.3881	.136528
G x T	1	1.0582	22	3.5749	.2960	.591864
Absolute VO2peak						
Group	1	1.1321	22	.1425	7.9427	.010011
Time	3	1.5077	66	.0130	115.8044	.000000
G x T	3	.0144	66	.0130	1.1045	.353648
Relative VO2peak						
Group	1	189.6188	22	26.8833	7.0534	.014438
Time	3	464.3136	66	2.0834	222.8604	.000000
G x T	3	18.9155	66	2.0834	9.0790	.000041
REE						
Group	1	404084.3	22	14983.42	26.9688	.000033
Time	3	586846.3	66	1968.81	298.0714	.000000
G x T	3	85146.5	66	1968.81	43.2477	.000000

Newman-Keuls Post Hoc Analyses

Total Body Weight			{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}
Group	Time		87.6325	85.8633	79.9992	77.1208	84.1192	83.3333	82.2150	79.7350
A	1	{1}								
A	2	{2}	.00155							
A	3	{3}	.00013	.00013						
A	4	{4}	.00013	.00013	.00012					
B	1	{5}	.00011	.00178	.00015	.00013				
B	2	{6}	.00015	.00014	.00011	.00013	.14434			
B	3	{7}	.00013	.00015	.00020	.00015	.00195	.03937		
B	4	{8}	.00013	.00013	.62111	.00012	.00013	.00015	.00015	

Percent Body Fat			{1}	{2}	{3}	{4}
Group	Time		37.2842	30.1783	34.0667	31.0692
A	1	{1}				
A	2	{2}	.00017			
B	1	{3}	.00016	.00014		
B	2	{4}	.00014	.12434	.00017	

Fat-Free Weight			{1}	{2}	{3}	{4}
Group	Time		55.0051	53.8647	55.5599	55.0134
A	1	{1}				
A	2	{2}	.15388			
B	1	{3}	.75519	.15555		
B	2	{4}	.99159	.31575	.48653	

Absolute VO2peak		{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}
Group	Time	2.3183	2.4581	2.6276	2.9536	2.1599	2.2415	2.4121	2.6754
A	1	{1}							
A	2	{2}	.01052						
A	3	{3}	.00015	.00065					
A	4	{4}	.00013	.00015	.00011				
B	1	{5}	.00335	.00013	.00013	.00013			
B	2	{6}	.10408	.00024	.00013	.00013	.08474		
B	3	{7}	.04810	.32704	.00016	.00013	.00016	.00152	
B	4	{8}	.00013	.00015	.30907	.00011	.00013	.00013	.00015

Relative VO2peak		{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}
Group	Time	26.5700	28.8083	33.0925	38.5417	25.6783	26.9517	29.4517	33.6875
A	1	{1}							
A	2	{2}	.00102						
A	3	{3}	.00013	.00011					
A	4	{4}	.00013	.00013	.00011				
B	1	{5}	.13512	.00016	.00013	.00013			
B	2	{6}	.51956	.00259	.00015	.00013	.08573		
B	3	{7}	.00019	.27901	.00011	.00015	.00013	.00031	
B	4	{8}	.00013	.00015	.31641	.00011	.00013	.00013	.00011

REE		{1}	{2}	{3}	{4}	{5}	{6}	{7}	{8}
Group	Time	943.360	1074.015	1210.645	1447.323	950.460	989.108	1041.627	1175.122
A	1	{1}							
A	2	{2}	.00013						
A	3	{3}	.00013	.00011					
A	4	{4}	.00013	.00015	.00011				
B	1	{5}	.69648	.00015	.00013	.00013			
B	2	{6}	.03681	.00015	.00013	.00013	.03669		
B	3	{7}	.00016	.07847	.00015	.00013	.00012	.00520	
B	4	{8}	.00013	.00011	.05421	.00011	.00013	.00015	.00011

Section 4: Correlation Matrix

Correlation Matrix
Split By: Group
Cell: A

	Wt	Fat	A VO2	R VO2	REE	FFW
Wt	1.000	.377	-.305	-.739	-.549	.807
Fat	.377	1.000	-.779	-.752	-.703	-.241
A VO2	-.305	-.779	1.000	.857	.779	.180
R VO2	-.739	-.752	.857	1.000	.827	-.296
REE	-.549	-.703	.779	.827	1.000	-.123
FFW	.807	-.241	.180	-.296	-.123	1.000

24 observations were used in this computation.

Correlation Matrix
Split By: Group
Cell: B

	Wt	Fat	A VO2	R VO2	REE	FFW
Wt	1.000	-.205	.152	-.421	-.238	.927
Fat	-.205	1.000	-.613	-.440	-.519	-.557
A VO2	.152	-.613	1.000	.828	.617	.365
R VO2	-.421	-.440	.828	1.000	.698	-.188
REE	-.238	-.519	.617	.698	1.000	-.004
FFW	.927	-.557	.365	-.188	-.004	1.000

24 observations were used in this computation.

Section 5: Multiple Regression Models

Regression Summary
REE vs. 5 Independents
Split By: Group
Cell: A

Count	24
Num. Missing	0
R	.850
R Squared	.722
Adjusted R Squared	.644
RMS Residual	160.162

ANOVA Table
REE vs. 5 Independents
Split By: Group
Cell: A

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	5	1197135.431	239427.086	9.334	.0002
Residual	18	461734.209	25651.901		
Total	23	1658869.640			

Regression Coefficients
REE vs. 5 Independents
Split By: Group
Cell: A

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	1190.894	4561.136	1190.894	.261	.7970
Wt	-22.251	78.220	-.773	-.284	.7793
Fat	2.769	107.138	.047	.026	.9797
A VO2	513.675	586.953	.755	.875	.3930
R VO2	-10.298	47.076	-.267	-.219	.8293
FFW	13.324	129.197	.297	.103	.9190

Regression Summary
REE vs. 5 Independents
Split By: Group
Cell: B

Count	24
Num. Missing	0
R	.741
R Squared	.549
Adjusted R Squa...	.424
RMS Residual	102.010

ANOVA Table
REE vs. 5 Independents
Split By: Group
Cell: B

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	5	227919.515	45583.903	4.380	.0088
Residual	18	187309.990	10406.111		
Total	23	415229.505			

Regression Coefficients
REE vs. 5 Independents
Split By: Group
Cell: B

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	2915.416	5173.276	2915.416	.564	.5800
Wt	25.174	102.634	1.397	.245	.8090
Fat	-52.482	130.142	-1.109	-.403	.6915
A VO2	219.134	742.349	.566	.295	.7712
R VO2	-2.098	58.503	-.074	-.036	.9718
FFW	-48.354	162.630	-2.137	-.297	.7696

Regression Summary
REE vs. 4 Independents
Split By: Group
Cell: A

Count	24
Num. Missing	0
R	.849
R Squared	.721
Adjusted R Squared	.663
RMS Residual	155.936

ANOVA Table
REE vs. 4 Independents
Split By: Group
Cell: A

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	4	1196862.627	299215.657	12.305	<.0001
Residual	19	462007.013	24316.159		
Total	23	1658869.640			

Regression Coefficients
REE vs. 4 Independents
Split By: Group
Cell: A

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	1633.170	1511.729	1633.170	1.080	.2935
Wt	-14.349	15.319	-.498	-.937	.3607
Fat	-8.210	11.714	-.141	-.701	.4919
A VO2	547.715	472.541	.805	1.159	.2608
R VO2	-12.980	38.205	-.336	-.340	.7378

Regression Summary
REE vs. 4 Independents
Split By: Group
Cell: B

Count	24
Num. Missing	0
R	.739
R Squared	.547
Adjusted R Squared	.451
RMS Residual	99.533

ANOVA Table
REE vs. 4 Independents
Split By: Group
Cell: B

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	4	226999.578	56749.895	5.728	.0034
Residual	19	188229.927	9906.838		
Total	23	415229.505			

Regression Coefficients
REE vs. 4 Independents
Split By: Group
Cell: B

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	1450.202	1535.970	1450.202	.944	.3569
Wt	-4.809	18.628	-.267	-.258	.7990
Fat	-13.892	9.369	-.294	-1.483	.1545
A VO2	123.732	653.166	.320	.189	.8518
R VO2	5.387	51.527	.191	.105	.9178

Regression Summary
REE vs. 4 Independents
Split By: Group
Cell: A

Count	24
Num. Missing	0
R	.849
R Squared	.720
Adjusted R Squared	.662
RMS Residual	156.240

ANOVA Table
REE vs. 4 Independents
Split By: Group
Cell: A

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	4	1195059.627	298764.907	12.239	<.0001
Residual	19	463810.012	24411.053		
Total	23	1658869.640			

Regression Coefficients
REE vs. 4 Independents
Split By: Group
Cell: A

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	2307.057	2268.703	2307.057	1.017	.3220
Fat	-26.839	24.783	-.460	-1.083	.2924
A VO2	579.836	525.713	.852	1.103	.2838
R VO2	-15.369	42.504	-.398	-.362	.7217
FFW	-22.678	25.352	-.505	-.895	.3822

Regression Summary
REE vs. 4 Independents
Split By: Group
Cell: B

Count	24
Num. Missing	0
R	.740
R Squared	.547
Adjusted R Squared	.452
RMS Residual	99.455

ANOVA Table
REE vs. 4 Independents
Split By: Group
Cell: B

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	4	227293.458	56823.364	5.745	.0033
Residual	19	187936.047	9891.371		
Total	23	415229.505			

Regression Coefficients
REE vs. 4 Independents
Split By: Group
Cell: B

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	1796.586	2379.391	1796.586	.755	.4595
Fat	-21.181	24.901	-.448	-.851	.4056
A VO2	171.805	698.878	.444	.246	.8084
R VO2	1.588	55.124	.056	.029	.9773
FFW	-9.161	29.494	-.405	-.311	.7595

Regression Summary
REE vs. 3 Independents
Split By: Group
Cell: A

Count	24
Num. Missing	0
R	.842
R Squared	.709
Adjusted R Squared	.665
RMS Residual	155.458

ANOVA Table
REE vs. 3 Independents
Split By: Group
Cell: A

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	3	1175526.171	391842.057	16.214	<.0001
Residual	20	483343.468	24167.173		
Total	23	1658869.640			

Regression Coefficients
REE vs. 3 Independents
Split By: Group
Cell: A

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	375.554	692.744	375.554	.542	.5937
Fat	-7.294	11.637	-.125	-.627	.5379
A VO2	136.216	173.581	.200	.785	.4418
R VO2	21.710	9.361	.562	2.319	.0311

Regression Summary
REE vs. 3 Independents
Split By: Group
Cell: B

Count	24
Num. Missing	0
R	.738
R Squared	.545
Adjusted R Squared	.477
RMS Residual	97.183

ANOVA Table
REE vs. 3 Independents
Split By: Group
Cell: B

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	3	226339.240	75446.413	7.988	.0011
Residual	20	188890.265	9444.513		
Total	23	415229.505			

Regression Coefficients
REE vs. 3 Independents
Split By: Group
Cell: B

	Coeffici...	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	1070.322	430.256	1070.322	2.488	.0218
Fat	-14.013	9.136	-.296	-1.534	.1407
A VO2	-41.900	119.743	-.108	-.350	.7301
R VO2	18.534	7.687	.657	2.411	.0256

Regression Summary
REE vs. 3 Independents
Split By: Group
Cell: A

Count	24
Num. Missing	0
R	.845
R Squared	.714
Adjusted R Squared	.671
RMS Residual	153.940

ANOVA Table
REE vs. 3 Independents
Split By: Group
Cell: A

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	3	1184916.867	394972.289	16.667	<.0001
Residual	20	473952.773	23697.639		
Total	23	1658869.640			

Regression Coefficients
REE vs. 3 Independents
Split By: Group
Cell: A

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	1096.427	1286.734	1096.427	.852	.4042
A VO2	570.453	465.391	.838	1.226	.2345
R VO2	-9.108	37.319	-.236	-.244	.8097
Wt	-13.453	15.070	-.467	-.893	.3826

Regression Summary
REE vs. 3 Independents
Split By: Group
Cell: B

Count	24
Num. Missing	0
R	.703
R Squared	.494
Adjusted R Squared	.418
RMS Residual	102.473

ANOVA Table
REE vs. 3 Independents
Split By: Group
Cell: B

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	3	205214.941	68404.980	6.514	.0030
Residual	20	210014.564	10500.728		
Total	23	415229.505			

Regression Coefficients
REE vs. 3 Independents
Split By: Group
Cell: B

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	943.498	1541.711	943.498	.612	.5474
A VO2	260.686	665.703	.674	.392	.6995
R VO2	-.145	52.910	-.005	-.003	.9978
Wt	-6.184	19.154	-.343	-.323	.7502

Regression Summary
REE vs. 2 Independents
Split By: Group
Cell: A

Count	24
Num. Missing	0
R	.838
R Squared	.703
Adjusted R Squared	.675
RMS Residual	153.194

ANOVA Table
REE vs. 2 Independents
Split By: Group
Cell: A

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	2	1166030.484	583015.242	24.842	<.0001
Residual	21	492839.156	23468.531		
Total	23	1658869.640			

Regression Coefficients
REE vs. 2 Independents
Split By: Group
Cell: A

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	-34.400	225.067	-34.400	-.153	.8800
A VO2	179.551	156.902	.264	1.144	.2654
R VO2	23.236	8.907	.601	2.609	.0164

Regression Summary
REE vs. 2 Independents
Split By: Group
Cell: B

Count	24
Num. Missing	0
R	.701
R Squared	.492
Adjusted R Squared	.443
RMS Residual	100.264

ANOVA Table
REE vs. 2 Independents
Split By: Group
Cell: B

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	2	204120.366	102060.183	10.152	.0008
Residual	21	211109.139	10052.816		
Total	23	415229.505			

Regression Coefficients
REE vs. 2 Independents
Split By: Group
Cell: B

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	448.144	147.986	448.144	3.028	.0064
A VO2	48.703	107.461	.126	.453	.6550
R VO2	16.740	7.838	.593	2.136	.0446

Regression Summary
REE vs. 1 Independents
Split By: Group
Cell: A

Count	24
Num. Missing	0
R	.779
R Squared	.607
Adjusted R Squared	.589
RMS Residual	172.224

ANOVA Table
REE vs. 1 Independents
Split By: Group
Cell: A

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	1006324.482	1006324.482	33.927	<.0001
Residual	22	652545.158	29661.144		
Total	23	1658869.640			

Regression Coefficients
REE vs. 1 Independents
Split By: Group
Cell: A

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	-202.119	242.481	-202.119	-.834	.4135
A VO2	530.156	91.018	.779	5.825	<.0001

Regression Summary
REE vs. 1 Independents
Split By: Group
Cell: B

Count	24
Num. Missing	0
R	.617
R Squared	.381
Adjusted R Squared	.353
RMS Residual	108.075

ANOVA Table
REE vs. 1 Independents
Split By: Group
Cell: B

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	158266.165	158266.165	13.550	.0013
Residual	22	256963.340	11680.152		
Total	23	415229.505			

Regression Coefficients
REE vs. 1 Independents
Split By: Group
Cell: B

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	485.387	158.403	485.387	3.064	.0057
A VO2	238.829	64.881	.617	3.681	.0013

Regression Summary
REE vs. 1 Independents
Split By: Group
Cell: A

Count	24
Num. Missing	0
R	.827
R Squared	.684
Adjusted R Squared	.670
RMS Residual	154.268

ANOVA Table
REE vs. 1 Independents
Split By: Group
Cell: A

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	1135297.474	1135297.474	47.704	<.0001
Residual	22	523572.165	23798.735		
Total	23	1658869.640			

Regression Coefficients
REE vs. 1 Independents
Split By: Group
Cell: A

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	154.638	153.933	154.638	1.005	.3260
R VO2	31.967	4.628	.827	6.907	<.0001

Regression Summary
REE vs. 1 Independents
Split By: Group
Cell: B

Count	24
Num. Missing	0
R	.698
R Squared	.487
Adjusted R Squared	.463
RMS Residual	98.436

ANOVA Table
REE vs. 1 Independents
Split By: Group
Cell: B

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Regression	1	202055.518	202055.518	20.853	.0002
Residual	22	213173.987	9689.727		
Total	23	415229.505			

Regression Coefficients
REE vs. 1 Independents
Split By: Group
Cell: B

	Coefficient	Std. Error	Std. Coeff.	t-Value	P-Value
Intercept	478.538	129.513	478.538	3.695	.0013
R VO2	19.683	4.310	.698	4.566	.0002